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EDITORIAL.

ITEMS AND NOVELTIES.

The Hoosac Tunnel.—This, one of the most extraordinary engineering labors ever projected in this country, was undertaken with the view of forming a more direct railway connection, and one more central to the State of Massachusetts, between the Hudson river and Boston, than that afforded by the principal route hitherto existing (the Boston and Albany Railroad). The Tunnel route—if carried to a successful culmination, and of this, the untiring energy and engineering talent of the Messrs. Shanly, the present superintendents of the enterprise, furnish the strongest grounds for belief—will have for its western terminus the city of Troy, and will be about ten miles shorter between that point and Boston than the existing route; while in respect to gradients, the tunnel line will have greatly the advantage over the latter, in having no inclines exceeding forty-five feet in the mile, against gradients of from eighty to ninety feet on the other.

The railways of which the tunnel is designed to be the connecting link, are already completed up to the mountains on either side. At the present time and until the completion of the tunnel, stages are in requisition to carry travellers over "the Hoosacs," to complete connections on either side. The westerly portal of the tunnel is at North Adams, fifty miles distant from Troy, and the easterly one is in the valley of Deerfield river, 136 miles from Boston.

The Hoosac Mountain, through the ribs of which the tunnel is being pierced, is, at its highest point along the line, 2508 feet above tide, and the two portals a trifle over 760 feet above the same. Lithologically, it consists, almost throughout, of mica schist, the westerly side displaying for half a mile or less a fault of somewhat altered granite, beyond which again a very hard quartzite is encountered for another half mile or more, which has not yet been fully penetrated. The east end workings, now upwards of 8000 feet inwards, are in unmistakable mica schist, occasional narrow veins of quartz being met with. At the "central shaft," which is located nearly midway between the two ends, and is 1030 feet in depth, the workings are through the same material.

The tunnel is designed for a double line of rails; its length, when completed, will be 25,031 feet; its width is 24 feet; height in centre, 20 feet; and it is graded from each end to the centre 6 inches in the 100 feet, ascending from either end.

The mountain has already been penetrated:

From the east side, ...	8200 feet.
From the west side, ...	5820 "
And at "central shaft,"	200 "
Showing a total progress in the work of .	14,220 "

And leaving still to be accomplished, 10,811 feet.

The daily progress averages at present 15 feet, which it is anticipated will be increased to 18 feet when machine drills have been introduced into the central workings; this, we understand, will take place in about two months.

The system of working varies with the locality. At the east end, where the greatest advance has been made, the work is more simple than at the west end or at the centre. Here (east) the rock is run out by an engine and train of cars, and disposed of in the valley of the Deerfield river. At the east end two operations are going forward. Nearly one-half mile from the portal inwards is in bad ground,

requiring to be arched with brick, the progress of which is necessarily slow, and the appliances for this work taking up the whole space of the tunnel, the rock from the solid workings farther in cannot be run out through the portal. This unlucky state of affairs necessitated the taking of the "bad ground" in the rear, by sinking a shaft, called the "west shaft," 318 feet deep, through which all the rock from the western workings, behind the portion requiring arching with brick, is hoisted. This is effected by a double lift, worked by steam power, one bringing to the surface a car loaded with rock, the other taking an empty car to the bottom. This alternate process goes on with great regularity, a car of rock emerging at the surface every $2\frac{1}{2}$ minutes.

Nearly midway between the ends of this tunnel, and in a deep depression of the mountain, another shaft has been sunk. Its depth is 1030 feet, its shape oval, and dimensions 27 by 15 feet. This is termed the "central shaft," and has recently been completed, and the work of driving the tunnel east and west therefrom commenced. The method of hoisting the rock here is identical with that at the "west shaft;" the machinery is, however, more powerful, and considerable pumping is required to keep the bottom workings free of water.

The drilling is chiefly done by the machine known as the "Burleigh Rock Drill," worked by compressed air, the air compressors being also of the Burleigh Rock Drill Company's make, the drills working either horizontally or vertically, as occasion requires. The material is taken out, full tunnel width, with the aid of eight of these machines, mounted horizontally on two carriages, which are run back—with the drills still in place—far enough to be out of harm's way during the operation of blasting, which is performed twice in each "shift" of eight hours. Of the drills it may be mentioned that each weighs about 540 pounds, and under a pressure of 60 pounds to the square inch will make upwards of 200 strokes per minute, drilling a hole $1\frac{3}{4}$ inches in diameter.

The air power for the drills is obtained through the agency of water power at the east end, and with the aid of steam at the other two points. It is compressed to give a pressure of 65 pounds on the square inch, and is conveyed to the point where it is needed through cast iron pipes, 8 inches in diameter, which are fitted with air-tight joints.

At the east end the work of compressing the air is carried on

upwards of 9000 feet from the point where the drills are in operation, the difference in pressure at the working points being only 2 pounds per square inch compared with that recorded without the tunnel. The exhaust from the drills furnishes a goodly supply of fresh air to the workmen, and the atmosphere of the workings, now 8000 feet from the outer world, is perfectly endurable.

The blasting is principally accomplished by means of nitro-glycerine, manufactured on the place, by Mr. G. M. Mowbray, an experienced chemist. This material, which must be handled with the most intelligent caution, is allowed only in the hands of those who are adepts in its use, and who are employed especially for that purpose.* Though its cost is ten times that of blasting powder, it is nevertheless found advantageous to employ it in certain portions of the works. In the nitro-glycerine blast, the number of holes simultaneously charged varies from ten to fifteen, their depth is usually 60 to 72 inches where the hole is horizontal; where it is vertical, the glycerine charge is put down 10 feet and upwards. These figures will, of course, vary with the nature of the rock and other conditions.

The labor employed in the work is chiefly of the kind termed "skilled labor," the underground workers being, for the most part, regularly bred miners (a large proportion of them being of the very best and most intelligent class of Cornish miners). There are also a large number of Irishmen employed underground, who are highly prized; while of the French Canadians, who are well represented, it is said their aptitude for learning has already made excellent miners of many of them. The overground men employed are chiefly mechanics and American. The employees number about 900, men and boys.

The work is carried on day and night (except Sunday), the twenty-four hours being divided into three working days or shifts of eight hours each.

Such, in brief, is an outline of the nature and present status of this most important work, the rapid and satisfactory progress of which reflects eminent credit upon its talented superintendents.

A new Fire-escape and Ladder.—At the last meeting of the Institute, there was presented and described a contrivance of this character, designed and patented by Mr. Tobias Witmer,

* See a very vivid description of this process in Vol. LVI., page 357, of this *Journal*.

of Buffalo. There are several points in construction for which the inventor claims great rapidity of movement from place to place, ease of attachment and management; these are, that the ladder is mounted permanently on wheels, and is furnished at its lower extremity with a lever. When in use it can be detached from the truck, or forward half of its carriage, readily raised—the angle of elevation being controlled by a rope and windlass attached at the outer extremity of the lever before mentioned—and run rapidly to any needful position. The top of the ladder is furnished with a car, arranged so as to preserve its verticality, at whatever angle the ladder may be, and designed for the reception of a fireman to manage the hose or render assistance, as the case may demand; while on the outer edge is attached a pulley, by which a stout canvas bag is raised or lowered by those below, and in which persons or goods can be taken from the burning edifice with safety. It may be added that the ladders are of the extension plan.

Magnetic Engines—their possible duty.—Attention has been drawn lately, in some of the public prints, to one or more forms of magnetic or electric engines claiming to develop an available and economic motive power. In view of this, it may be of interest, or even of use, if we put before our readers, in a few words and figures, the *possibilities* of invention and improvement in this direction.

The total mechanical equivalent of a pound of pure carbon consumed with oxygen is $7900 \times 1390 = 10{,}981{,}000$ foot pounds,* or in other words, one pound of pure coal burned in one minute would if applied with *absolute* economy to the development of motion, exert a force of $\frac{10{,}981{\cdot}000}{33{\cdot}000} = 332$ horse-power *during one minute*, or if burned during an hour, would exert $\frac{332}{60} = 5{\cdot}5$ horse-power *during the hour;* or again, each horse-power would require $\frac{1}{5{\cdot}5} = {\cdot}18$ of a pound of coal per hour, nearly, or say $\frac{1}{5}$ pound. Now, as a matter of fact, a good engine and boiler does develop a horse-power for each 5 pounds of coal consumed, being about $\frac{1}{25}$th, or say 4 per

* Note.—By Andrews' experiments, one pound of carbon, burned with free supply of oxygen, will heat 7900 pounds of water one degree centigrade. The mechanical equivalent for the heating of one pound of water one degree centigrade is 1390 foot-pounds.

cent. of what it might do if a perfect machine. This shows us that there is a large margin for improvement in reference to the duty of our steam motors, and that if in any other way, chemical force can be converted into motion in a less wasteful way, *some* increase in the costliness of the fuel may not be inconsistent with economy. But this, like any other problem, has its limits, and these it is our purpose to define.

The total mechanical equivalent of zinc is $1301 \times 1390 = 1{,}808{,}390$, or, in other words, a pound of zinc consumed with oxygen in one minute would, if applied with *absolute economy* to the production of motion, develop a force of $\frac{1{,}808{,}390}{33{,}000} = 55$ horse-power, during that time; or, during one hour, $\frac{55}{60} = \cdot 91$, or, say, one horse-power.

Or, in other words, zinc being consumed in such a way that its total useful effect should be applied *without any loss whatever*, would, weight for weight, be about five times as effective as coal in its present wasteful manner of consumption. When, then, zinc is less than five times as costly as coal, and a *perfect* battery and electric engine have been invented, these will compete favorably with the steam engines of the present day.

With reference to some statements that have been published, it may be interesting to note that, from the above data, it is evident that with a *perfect* battery and engine, to develop $2\frac{1}{2}$ horse-power for 10 hours, would demand the consumption of 27·4 pounds of zinc.

Injectors and Pumps.—We observe, in our able cotemporary, *Engineering*, a statement which will no doubt interest many of our readers, namely, that in England and on the Continent hundreds of locomotives are running with injectors alone, and without being supplied with feed pumps also, as is so generally the custom in this country, while hundreds also have only one injector as their sole supply, and yet that occasions of failure even under this last condition are exceedingly few.

Electric Light.—In some experiments made at St. Petersburgh it was found that by aid of an electric light, a target at 1660 yards was so well illuminated that, with an ordinary field-piece, the balls could be invariably lodged as truly as in daylight. Objects at some

distance, on either side of the target, were also rendered clearly visible.

Steel Tyres.—A number of accidents which have occurred from the breaking of steel tyres during the late severe cold, draws attention to the fact that a very unnecessary degree of hardness is often given by manufacturers to these parts. The desire to obtain a maximum of mileage among competing makers has gradually led to the use of a steel whose hardness is in excess of what a due regard for security from breakage would warrant.

This, however, is not the only condition involved. The amount of shrinkage should be proportioned to the elasticity of the tyre, and also to the rigidity of the wheel. In rapid running, say of an express train, at 50 miles per hour, the strain developed by centrifugal force amounts to about 4 tons per square inch of section. The shrinkage strain should be a little in excess of this. Now, a steel tyre, of average quality and hardness, on a perfectly rigid wheel, will develop a strain of about $3\frac{1}{2}$ tons per square inch for each $\frac{1}{100}$th inch shrinkage allowed per foot diameter. Thus, $\frac{1}{50}$th inch per foot, or about $\frac{1}{16}$th inch, in a tyre of 3 feet internal diameter, would involve an initial tension of 7 tons per square inch. But the yielding of the wheel which would in practice occur, would probably reduce this strain to 4 tons. These calculations are based on the assumption that the steel will stretch about $\frac{1}{1250}$th per ton of strain. If the steel is harder, however, the strain will be greater, and so the old rules for shrinkage will, with harder steels than those on which they were calculated, develop an undue strain. The change in temperature acting equally on wheel and tyre, has probably little effect in causing the breakage of tyres, which is rather due to the severer shocks developed by the frozen and rigid permanent way. We owe the material of the above abstract to our able cotemporary, *Engineering*.

Boiler Incrustation.—Among the many means proposed for the prevention of this cause of danger, loss, and inconvenience, too little attention has been given to those which might be described as preventives rather than cures. The preliminary purification of water by filtration, and by chemical treatment, such as the precipitation of carbonate of lime by lime water, known as Clark's method, and the use of surface condensers, either of the immersed or of the evaporative type, are worthy of attention in many cases where less effective, and, in the end, more costly means are now in use.

Ocean Telegraph—running speed.—The French Atlantic cable has been occasionally sending as many as 10,000 words per day of 24 hours, but the usual business on the line is about 7000 words daily, or 5 words a minute for 24 hours.

A Screw Propeller Ferry Boat.—The Grand Trunk Railway of Canada has imported an iron ferry boat, with twin screws, to run between Fort Erie and Buffalo and Sermia and Port Huron. She is something over 300 feet long, 45 feet beam, 14 feet deep, and can carry an entire train, with locomotive. She was built at Jarrow, by Messrs. Palmer & Co., and will be put together at Fort Erie by Mr. T. Campbell.

Varied Strain on Railroad Wheels.—From experiments of Baron Von Werder, mentioned in *Engineering*, it appears that the oscillation of six-wheeled locomotives about their central axes, produces such varied strains upon the leading and trailing ends alternately, that in the engines experimented with, the greatest load thrown upon the springs in this way, exceeded the normal load, by 103 per cent. in the case of the leading springs, and 74 per cent. in the trailing springs. These maximum loads are much greater than that allowed by German railroad authorities. The load upon the spring is sometimes reduced during running to about 7 per cent. of the normal load for the leading springs, and to 26 per cent. for the trailing springs. It appears also certain that there are horizontal movements of the vehicles produced at first by partially vertical oscillations. As these horizontal movements towards a rail, may often coincide with a relief of load upon that rail, we have an explanation of widening of gauge and displacement of the permanent way; for, under the circumstances supposed, the opposition of the latter is only that due to its mechanical structure. The difference between the maximum and minimum loads resting at different times on the same springs, varies by more than double the normal load for the leading wheels, but seldom more than 40 per cent. for the trailing wheels. The dangers resulting from this varying and excessive pressure are evident, and demand a system of construction for vehicles which will prevent, or at least reduce, the shifting of load, and such a structure of the permanent way as will distribute the load over a considerable distance.

Bridge across the Hudson River, near New York.—Plans and other preliminaries for this undertaking are in an advanced

condition, and there seems now little doubt that this vast work will be actually put in hand.

The great obstruction to crossing which has been experienced during this season, from the unusual accumulations of ice in the river, will no doubt give a favorable impetus to the project.

A new Air Engine.—In this engine the air is compressed by stages, and passed at each stage through water. It becomes saturated with moisture, and the heat given out by compression is so completely absorbed by the water that under no circumstances the pumps become heated. In the first pump the air is compressed from 1 to 3 atmospheres, in the second from 3 to 6, in the third from 6 to 12, and in the fourth from 12 to 24. From this last pump the air is conducted into a reservoir, whence it passes, in a thoroughly saturated condition, to the coil in the heating chamber. Here the suspended water becomes steam, and the compressed gas is expanded. From this coil the cylinder of the engine is supplied with motive power. In the trial engine the cylinder is $4\frac{3}{8}$ inches in diameter, with a 6-inch stroke, and the effective power over and above that required to work the pumps is stated to be 4 horse-power, the amount of fuel consumed being only $2\frac{1}{2}$ ponnds per H. P. per hour.

Scientific Lecture on the grand scale.—We see, from the New York papers, that Prof. Morton's lecture on Vision, at the Academy of Music in that city, was a decided success. His optical experiments, developed upon a scale never before attempted in that place, were received with great approbation and enthusiasm. We have been promised a detailed account of his new apparatus and experiments, with illustrations.

Browning's Spectroscope. *—Mr. Browning, the eminent optician, has devised a spectroscope, in which the prisms are automatically adjusted for the minimum angle of deviation for the ray under examination.

In spectroscopes of ordinary construction, when several prisms are employed, a great deficiency of light will be noticed towards the more refrangible end of the spectrum.

This arises from the fact that the prisms are adjusted to the minimum angle of deviation for the most luminous rays which occupy the middle of the spectrum. The effect of this is shown in Fig. 1, P P.

In Fig. 1, P P, &c., represent a train of prisms adjusted as just

* An abstract from the *Chemical News*, communicated by the Editor.

described, for the central portion of the spectrum, and screwed firmly in their places. T represents a telescope, moving round a centre situated at K. In the position in which the telescope is placed, the whole field of the object-glass would be filled with the green light of the spectrum issuing from the last prism; but, when the telescope is removed to the position shown by the dotted lines, either nearer to R or to V (in which case the red end or the violet end of the spectrum would be in the field of view,) then, as we see by the lines, only a small portion of the spectrum would fall on the object-glass. But, it is obvious that, owing to the deficiency in light at the extreme ends of the spectrum, it is just in these very positions that it is desirable that the whole field of the object-glass should be filled. Now this can only be effected when the prisms are adjusted to the minimum angle of deviation for the particular portion of the spectrum which is being examined.

Fig. 1.

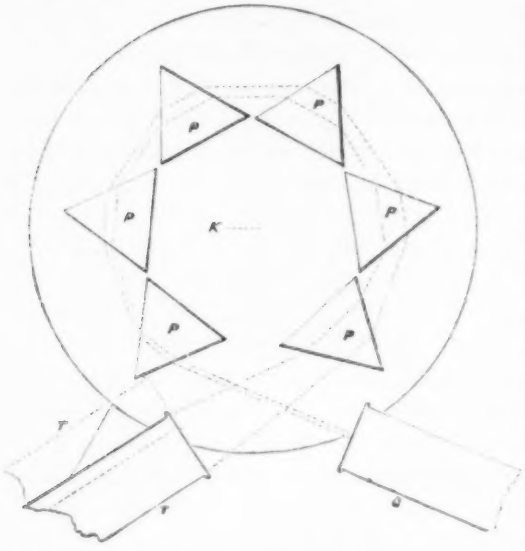


Fig. 2 shows the method in which the change in the adjustment of the prisms to the minimum angle of deviation for each particular ray is made automatically.

In this diagram, P P, &c., as before, represent prisms.

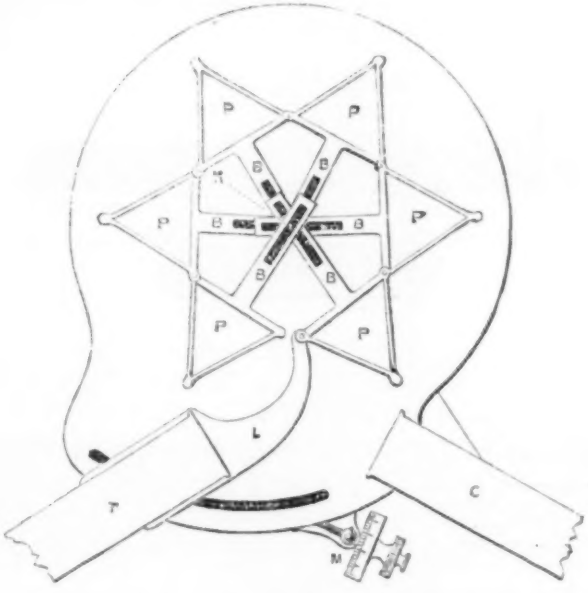
All these prisms, with the exception of the first, are unattached to the plate on which they stand, the triangular stand on which the prisms are hinged together at the angles corresponding to those at the bases of the prisms.

To each of these bases is attached a bar, B, perpendicular to the base of the prisms. As all these bars are slotted and run on a common centre, the prisms are brought into a circle. This central pivot is attached to a dovetail piece of two or three inches in length,

placed on the under-side of the main plate of the spectroscope; which is slotted to allow it to pass through. On moving the central pivot, the whole of the prisms are moved, each to a different amount in proportion to its distance in the train from the first or fixed prism on which the light from the slit falls after passing through the collimator, C. Thus, supposing the first prism of the train opposite C, represented in the diagram, to be stationary, and the second prism to have been moved through 1° by this arrangement, then the third prism will have moved through 2°, the fourth through 3°, the fifth through 4°, and the sixth through 5°. As these bars are at right angles to the bases of the prisms, and all of them pass through a common centre, it is evident that the bases of the prisms are at all times tangents to a common circle.

The contrivance by which this arrangement is made automatic is as follows:

Fig. 2.



A lever, L, is attached to the corner of the triangular plate of the last prism. This lever, by its further end, is attached to the support which carries the telescope through which the spectrum is observed.

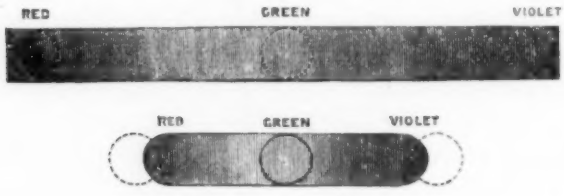
Both the telescope and lever are driven by the micrometer screw, M The action of the lever is so adjusted that when the telescope is moved through any angle it causes the last prism to turn through double that angle.

The rays which issue from the centre of the last prism are thus made to fall perpendicularly upon the centre of the object-glass of the telescope, T, and thus the ray of light travels parallel to the basis of the several prisms, and ultimately along the optical axis of the telescope itself, and thereby the whole field of the object-glass is filled with light.

Thus the apparatus is so arranged that on turning the micrometer screw, so as to make a line in the spectrum coincide with the cross wires in the eye-piece of the telescope, the lever, L, attached to the telescope and prisms, sets the whole of the prisms in motion, and adjusts them to the minimum angle of deviation for that portion of the spectrum.

Figs. 3 and 4 represent the appearances presented when looking through the telescope from which the glasses have been removed; in diagram 3 it will be seen that the whole circle of the object glass

Fig. 3 and 4.



is filled with light, as, I have just described, is the case with the new arrangement; while diagram 4 shows the effect of moving the telescope through the angle in front of the fixed prism.*

Coincidence of Terrestrial magnetic change with solar action.—In our November number we published a paper by Prof. C. A. Young, in which an account was given (among other things) of the sudden outburst upon the surface of the sun of a luminous

* It is with no wish to detract from Mr. Browning's credit, but simply to put before our readers the *fullest* information on each subject, that attention is called to the fact that Mr. L. M. Rutherfurd published in *Silliman's Journal* for March of 1865, an account of a spectroscope which involved the most important feature of the above, namely, the connection of the prisms by their bases and the attachment to these bases of bars with slots sliding on a common centre pin.—H. M.

cloud, whose shape and dimensions, as seen in the spectroscope, was represented in Fig. 9 of the same article. This outburst occurred exactly at 4·05 P. M. on September 28th.

In a letter just received from Prof. Young he mentions that on a careful examination of the magnetic record which is automatically kept at Greenwich, England, he found a sudden and marked inflection, amounting to no less than 5 minutes of arc, to have been produced exactly at this same instant of time.

A similar incident to this, but less definitely noted, was recorded by Herschel. See this *Journal*, Vol. LIV, p. 55.

Approach caused by Vibration.—It was first observed by Frederick Guthrie, that a delicately suspended piece of card-board, moves from a considerable distance towards a vibrating tuning fork. At first it seemed natural to suppose that this was the result of such small whirlwinds as Faraday had demonstrated to be the cause of inter-nodal accumulation of light particles on vibrating plates. A series of experiments, however, showed that these currents did not exist in the positions or reach to the distances demanded by this hypothesis.

One prong of a fork being enclosed in a tube connected with a simple tube, dipping in water, it was found that an expansion of the contained air was the immediate result of vibration in the fork.

Mr. Guthrie concludes, from the suddenness of this change in volume, and of its disappearance, that it was not due to heat developed by motion in the air. We do not, however, agree fully in this conclusion, as, under the conditions of the experiment, this gain and loss ought to be very rapid, and, on general principles, ought to occur.

Other experiments seemed to fail in demonstrating that a specific decrease in density was produced in an elastic medium by the development of sonorous vibrations therein, although such a result would seem to be a necessary consequence of general theory. We should doubt, in this case, if the delicacy of the test applied was sufficiently great.

The author finally concludes by what is little more than a general form of expression for the fundamental fact, namely, by stating that the dispersion of vibration between fixed surfaces produces effects similar to the dispersion of air currents under like conditions, (as in Clément's experiment, known as the pneumatic paradox, in which air emitted from a tube with a broad flange against a disk causes

the latter to approach,) and then farther generalizes to the effect that emitted heat vibrations might cause the approach of bodies, a conclusion, we think, very far from being warranted by the preceding facts and inferences.

Remarkable color change produced by heat in certain Iodides.—We have received from Prof. G. F. Barker specimens of the curious iodides of silver and of copper lately discovered by Meusel. The first of these is prepared by adding a solution of silver nitrate to one of mercuric iodide in potassium iodide, and is of a bright lemon-yellow color, changing by a heat below 212° to a rich orange, and regaining its original tint when cooled. The second is prepared by adding to a warm solution of mercuric iodide in potassium iodide, first copper sulphate and then sulphurous acid. Its color is carmine, becoming black, however, at a temperature of 158° F., but restored on cooling.

Mixed with gum water and applied to paper, these bodies exhibit their changes of color in a most striking manner.

Leaden Bullets melted by impact.—It will no doubt be remembered by some of our readers that when a stream of bullets was directed against an iron target from Perkins' steam gun, a homogeneous mass of lead was produced by the partial melting and reunion of the mass. In No. 7 of *Poggendorff's Annalen* for 1870 we find detailed record of a similar phenomenon, as observed in some experiments at Basle, where bullets weighing 40 grammes were discharged against an iron target at 100 paces. The bullets, after impact, weighed only 13 grammes, the remainder being melted and scattered about in a form bearing witness to its fluid condition. Mr. Ed. Hagenbach calculates the amount of heat which should be developed by the impact of the 40 guns, at a velocity of 320 metres per second, and finds it to be ·49 units, while the heat required to raise the temperature of the ball from 100° C, its presumable initial degree, to the melting point of lead, 335° C, and for fusing 27 grms., would be ·44 units. Thus showing, as might be supposed in advance, from the suddenness of the action, that almost all the heat developed is applied to this heating and fusion, and but little expended in producing motion in the target, or lost by radiation.

Boiling produced by commingling immiscible liquids.—In consequence of the fact that (as shown by Magnus) the vapors of liquids which do not mix obey Dalton's law of diffusion, the common tension of such vapors (as bisulphide of carbon and water) in a

state of saturation is equal to the sum of the individual tensions for the temperature in question. For example, bisulphide of carbon alone boils at 119·8 F., with a tension at this point of one atmosphere. The tension of water vapor at the same point is 0·11 of an atmosphere; the sum of these is, of course, 1·11 atmospheres, which would clearly imply an energetic ebullition in a mixture of bisulphide of carbon and water at this temperature.

That such a result would actually follow, may be readily illustrated in the following manner: Let a vessel of about one gallon capacity be filled with water at a temperature a little below 119·8° F., and a test tube partly filled with bi-sulphide of carbon be immersed and stirred about in the same until it has acquired an equal temperature. No boiling will occur, but if the contents of the test tube be now poured into the water a brisk ebullition will at once take place.

The maximum of Magnetic Power evolved by a Galvanic Battery.—A curious succession of papers on the above subject have appeared lately in the *Chemical News*, from the Rev. H. Highton, in which that gentleman attacks no less important a principle than the conservation of force, and maintains no less difficult a thesis than the possibility of what is technically called perpetual motion, or the development of power without a corresponding expenditure of force. The subject would hardly be worthy of our notice but that, strange to say, these opinions have gone, so far, unchallenged in the pages of our learned cotemporary, and, in connection with schemes alluded to in another item on galvanic motors, seem to have led astray some investigators.

The theory of the daring author above-named, is briefly this: A battery current, passed through a given electro-magnet, will lift a given weight; if, now, we double the cross section of the wire of said electro-magnet, and also its length, the resistance of the circuit remaining the same as before, the current developed by the battery and the consumption of zinc will remain as before, and yet the lifting power of the magnet will be doubled. Or, in place of increasing the size and length of wire, several similar electro-magnets may be so introduced in the circuit as to produce the same effect. Such a process continued indefinitely would, of course, enable us to develop any amount of magnetic force from a given battery.

So far, well; but we have not yet come to the development of power, which implies motion. For this, it is evident that the

electro-magnet must be charged and discharged, and here comes the compensating condition. To charge a *double length* of wire will take just *twice the time*, and therefore cause a *double expenditure* of zinc in the battery.

Our author, in fact, notices this, but remarks that "the electric current is so rapid that this difference of time is inappreciable within any practical limits." Without doubt, to advocates of perpetual motion, but not to those who can see that two millionths of a second are as much twice one millionth as two centuries are twice one; or to the zinc, which, having to work twice as long at each effort, will be doubly exhausted when a given number of actions has been completed.

Gold Refining by Chlorine.—On page 13 of our LVIIIth Volume we noticed the introduction, in the Australian Mint, of this process, with marked success. We now hear, from the best authority, that the inventor of the process, Prof. Miller, of the Royal Mint in Sydney, has just been putting up and working the apparatus in the Mint at Philadelphia, with very satisfactory results.

A bar of some 500 ounces, containing antimony, which rendered it very brittle and 7·80 fine, was refined in one hour and a half to a fineness of 9·97, and made perfectly tough, every trace of antimony having been removed.

The impure gold being melted in a crucible previously saturated with melted borax, and having a layer of fused borax over the metal, the gas is generated in a stone-ware vessel, and led by a flexible hose to a pipe-clay tube, by which it is carried to the bottom of the metal. All the chlorides of antimony, tin, &c., are so volatile at the temperature employed as to escape, but the silver chloride is retained by the layer of borax, and is poured out into moulds after the gold has become solid on cooling.

Reducing Silver Chloride.—In connection with the process for refining gold, described above, an excellent method for reducing the silver-chloride obtained in that operation has been perfected by its inventor, Prof. Leibius, Assayer of the Mint at Sidney. The silver-chloride is cast in flat plates, and then arranged in a box or frame, with alternate plates of zinc coupled as for a galvanic battery. The whole being immersed in water, a galvanic action is set up, the reduction is soon finished, and the silver is so compact and free from zinc that, without acid treatment, it may be carried to the melting pots.

Civil and Mechanical Engineering.

IRON MANUFACTURES IN GREAT BRITAIN.

SECOND PAPER.

By R. H. Thurston,

First Asst. Eng., Asst. Prof. Nat. Philos., U. S. N. A.; Member Institute.

The "Royal Navy" of Great Britain, like its merchant navy, is now composed, in its effective force, almost exclusively of iron steamers. Wooden vessels are not built, for all the reasons that apply in case of merchant ships, and for the additional reason that such weight of iron armor as has become necessary would prove very destructive to a wooden hull, even were the wooden hull capable of sustaining the strain of the immense steam power required for speeds of from twelve to sixteen or seventeen knots.

The war vessels built by Great Britain for some years past have been iron-clad, with the exception of a few transports, and several ships built with the intention—which was not realized, however—of competing with our own "Wampanoag class" in speed, regardless of their other naval qualifications.

In her navy of over six hundred registered vessels of all classes, she has now forty-seven iron clads, of which thirty-three have iron hulls, and of which more than-three-fourths are broadside ships. Their side armor varies from 4½ inches in thickness in the older broadside vessels, to 14 inches in the turrets of monitor iron clads now building. Their armament has its maximum in the "Hercules," which carries eight 18-ton X-inch rifles, two 12-ton IX-inch, and four 6½-ton VII-inch rifles, all of the Woolwich pattern.

The hulls of the later iron clads are of immense strength, and yet of comparatively light weight, their lightness in both hull and machinery enabling them to carry great weight of armor on a relatively small displacement. For the ingenuity which has so greatly and advantageously modified the details of construction of the hull, credit is very largely due to the energy and boldness of a talented engineer and naval architect, E. J. Reed, until recently, Chief Constructor of the British Navy.

The extreme lightness of machinery is obtained by high piston

speed and by great care in proportioning details; the boilers are forced to the utmost possible extent. The weight of engines and boilers with water has been in some cases brought below 300 pounds per indicated horse-power. Sharp competition between rival building firms and good engineering have given rise to rapid improvement, and have compelled the introduction of higher pressure, greater expansion, surface condensation, tubular boilers, and moderate superheating.

The style of engine is usually either the trunk engine, as built by Messrs. Penn & Sons, or of the ordinary "return connecting rod" type. The steam is usually carried at about 30 pounds per square inch in the boiler: in a few cases, one of which was given in the preceding paper, much higher pressures and the compound engine have been tried, by way of experiment, with, on the whole, very favorable results. It must be remarked, however, that the introduction of higher steam and greater expansion in new styles of engine has been, and will probably continue to be, retarded by the necessity of training men to manipulate successfully the new machinery, precisely as the introduction of surface condensers—now deemed so generally indispensable—was for years retarded.

A tolerably accurate idea of British design and proportion in constructing both hull and machinery may be obtained by reference to the description of the iron clad "Monarch," in the April, 1870, number of this *Journal.*

The cellular structure and bracket plate system of ship construction there described is adopted in all lately built iron clads and large vessels, and the proportions of machinery as there given are about the same as are generally adopted by the well known firms.

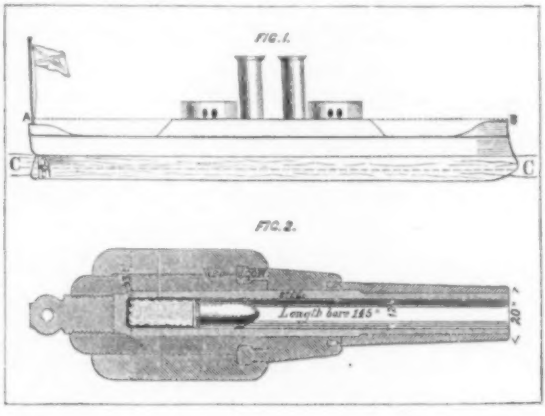
Although, as a general rule, the broadside iron clad has been adopted in the British navy, there are a few monitor iron clads afloat, and a number of others are building, in compliance with the feeling in their favor awakened by a strong party, headed by the late ill-instructed and unfortunate, but zealous inventor, Capt. Cowper P. Coles, R. N.

Those built since the "Monarch" are true Monitors, without masts and sails, and some of them are very formidable fighting machines. The loss of the "Captain" has caused a not remarkable, but somewhat unreasonable distrust of all ships of the monitor type; no more will probably be built of the "Monarch" class, and even the true monitors—without sails—are looked upon generally with much

the same feeling that was shown in our own navy when that class of vessels was first introduced.

One good effect that has followed the loss of the "Captain" is the commencement of a careful investigation of the stability of all British iron clads by experiment. There are some indications that their designers have sometimes been satisfied with obtaining a good height of metacentre above the centre of gravity without noting carefully its variation of position with the movements of the vessel, or laying off the curve of stability. It seems quite certain that in some classes of ships stability is seriously lacking, and orders have issued from the Admiralty, directing, in such cases, the use of a permanent ballast of iron concrete in the spaces of the cellular bottom.

The favorite style of turret iron clad is what its designer calls the "breastwork monitor," of which we gave a sketch in Fig. 1, the parts above the *dotted* line C C indicating armor.



The breastwork rises some six feet above the main deck of the vessel, and in the deck which covers it are the hatches, and through it rise the ventilators and smokepipes. There seems to be no reason why the same deck should not be carried fore and aft, as indicated by the dotted line, A B, and the covered but unarmored space thus utilized would be most valuable in these ships, which are invariably very much cramped in space below decks, and the change would greatly increase their stability. In one case, at least, this improvement is ordered.

The most formidable of these vessels are the "Devastation" and the "Thunderer," building respectively at Portsmouth and Pembroke dockyards, and now well advanced. These ships are 285 feet long, of 62½ feet beam, and will have a draught of 26 feet; their tonnage is given at 4406 tons. Their side armor is 12 inches thick, in single thickness, along the water line, and on breastworks, and somewhat thinner below water; the armor rests on teak backing, 18 inches thick, and an inner skin 1½ inches thick; the deck rises 4½ feet above water. The turrets are 31 feet in diameter, armored with 14-inch plates on the side through which the ports are cut, and 12 inches on other parts, backed with 15 and 17 inches of teak on an inner 1¼-inch skin. The bow is of immense strength, for the purpose of being used as a ram. These powerful craft carry four 30-ton XII-inch rifles, in two turrets, at a height of 12 feet above water; the shot fired by these guns will weigh something over 600 pounds, and will be propelled by 100 pounds of such powder as is used in the 70 pound cartridges of the "Monarch's" guns. The vessels are intended to have a speed of 12½ knots per hour, and to carry 1600 tons of coal in their bunkers, a quantity sufficient for, probably, ten days steaming; they have twin screws, driven by engines of 800 nominal horse-power collectively.

The most powerful *broadside* ships are the sister ships, "Hercules" and "Sultan." The structure of their hulls is quite similar to that of the "Monarch," and their armament has already been stated.

Their armor has a maximum thickness of 9 inches along the water line, 8 inches over the casemates, and 6 inches on the sides generally, backed with 12 inches of teak backing on a 1½-inch skin; along the thick water-line belt, a further protection of 30 inches of teak on another ¾-inch iron skin is added inside the hull. Their speed is from 13 knots at sea to 14¾ knots on the measured mile, on a displacement of 8,680 tons, a draught of 25 feet water, and driven by engines that have, in the "Hercules," indicated as high as 8,528 horse-power. This immense power has been developed with a consumption of 25 pounds of steam per H. P. per hour, as calculated from indicator cards; the grate surface is 907 feet square feet, heating surface 19,800, superheating surface 3,900, and condensing surface 20,768 square feet. The engines have cylinders of 127 inches diameter, and 47-inch trunks; stroke of piston, 4½ feet. Their weight, with that of boilers and water, is given at 1095 tons.

The machinery of both ships is from the same drawings, and is built by Messrs. Penn & Sons.

Visiting the "Sultan," at Chatham, we noticed the same absence of useless finish and ornament about the machinery that is almost invariably to be observed on British war vessels. The general design and arrangement and the proportions are admirable, and the workmanship excellent.

Two unarmored gunboats are just added to the British navy, which are remarkable for carrying, on a very small hull, a very large gun; they are of 85 feet length, 26 feet beam, and 9 feet depth of hold, measuring 244$\frac{75}{94}$ tons O. M.; they each carry one 18-ton X-inch rifle, and will probably prove very useful as well as inexpensive craft for harbor defence.

The 178,000 tons of vessels which constitute the British iron clad navy carry 590 guns, discharging 62,000 pounds of shot. These guns consist entirely of Woolwich rifles, the most powerful being the XII-inch rifles ordered, but not yet supplied, for the "Devastation" and the "Thunderer." One now about ready weighs 35 tons 7 hundred weight, measures 4 feet 8 inches across the breech, 1 foot 9 inches diameter at muzzle, and will cost about £2500. It is constructed on Frazer's modification of the Armstrong system, as are all large guns made at Woolwich; if made by the old method its cost would have been about £3500. Fig. 2 is a sketch of the "Monarch" pattern of XII-inch gun. The "*energy*" of the shot* from the gun just described will probably be about 7000 foot-tons at 1000 yards from the gun, and they will probably be capable of penetrating armor plate 15 inches thick, using charges of 100 or 120 pounds of powder.

The armament of the turret ships generally consists of 25-ton XII-inch rifles, and the heaviest guns in broadside are the 18-ton X-inch rifles. The latter throw a shot of 400 pounds with a velocity of 1200 to 1300 feet per second, and with a power sufficient to penetrate about 13 inches of iron; their "energy" at 1000 yards is still 3500 to 4000 foot-tons; the charge of powder is 60 pounds of English "large grain rifle powder." Less powerful vessels carry 12-ton IX-inch, 250 pdr. rifles, which are capable of penetrating, with a 45-pound charge, 11 inches of armor plate.

The guns made at Sir William Armstrong's "Elswick Works,"

* The first of these guns has been tested since the above was written, and the "energy" at 1000 yards is considerably above even the figure given.

as well as those made at Woolwich, are "built up guns." The inner tube is usually made of a mild steel, from the works of Messrs. Firth & Son, Sheffield. This steel tube is relied upon principally for longitudinal strength, and has also sufficient hardness to bear the severe friction of the shot without injury. Outside this steel tube are fitted a number of wrought iron bands, which are made of coiled bars welded together, somewhat like the old "stub twist" barrels. The bands are "shrunk on," the gun being kept cool during the operation by a cooling stream of water on its interior surface.

At the Elswick Works, near Newcastle-on-Tyne, where we were very kindly received by Sir William Armstrong and Capt. Noble, we found guns in process of manufacture for nearly every European government. All large guns were muzzle loaders, but army, battery, and siege guns, up to 40-pounders, were breech loading. We noticed here, as in many other large establishments, that all wrought iron chips and shavings were carefully gathered up and worked into blooms, in either reverberatory or open furnaces, a piece of economy that is less often noticed among our own iron workers. We noticed at the Elswick Works a Moncrieff gun carriage that, we fancied, looked rather weak at one or two important points; it would be very unfortunate if so excellent an invention were condemned in consequence of imperfection in design. All gun carriages were of iron, and were fitted with what is called, in England, the *Armstrong*, but in this country the *Ericsson* compressor.

The Armstrong and Woolwich guns are perhaps as strong as ingenuity and fine workmanship can make them with such materials, but it is evident that their numerous welds, and the varying strains liable to occur in shrinking on their bands, are seriously objectionable, and it consequently happens that the charge of the 25-ton gun is but about one-thousandth, and the weight of shot but one-ninetieth, the weight of the gun.

In many respects the *Whitworth* system of ordnance seems preferable, even if we take exception to the polygonal bore. Through the kindness of Sir Joseph Whitworth and of Mr. E. J. Reed, who had resigned his office of "Chief Constructor of the British Navy," for the purpose of joining the Whitworth Company, we were enabled to inspect their works and methods.

The Whitworth gun, as now made, is built up in a manner somewhat similar to the guns we have described, but steel is used en-

tirely, instead of wrought iron, in the bands. Formerly, the gun was made, in all its parts, of Firth steel, like that used at Woolwich for inner tubes, but recently the "Whitworth compressed metal" has been adopted. The compression of the metal, which is a "low steel," or "homogeneous metal," is effected while it is still molten in the mould, by an ingenious method of applying the tremendous force of a hydraulic press. This pressure, which has been carried up to 8 tons per square inch, and which will be increased to 20 tons per square inch, should it be found possible to sustain such a strain, by using moulds encased in the compressed metal, closes the pores, which ordinarily are found so seriously to injure the strength of steel castings, and the metal is given a homogeneity that is usually only obtained by forging under a heavy hammer. It is claimed that a metal can be thus obtained that can be relied upon for a tensile strength of 100,000 pounds per square inch, and a capability of stretching 25 per cent. before breaking. A metal which unites such high tensile strength and great resilience is evidently excellently adapted for ordnance purposes.

The several bands of the Whitworth ordnance are forced on, after being fitted with remarkable nicety, by means of the hydraulic press; the desired "initial tension" is thus obtained with great accuracy. The strength of these guns may be inferred from the fact that the charge of powder is usually about one seven-hundredth, and the weight of shot about one-*sixtieth*, of the weight of the gun.

Its penetration and range are probably, with equal weight of gun, about 20 per cent. greater than the Woolwich gun. It need hardly be stated that engineers generally seem to consider the Whitworth superior to the Woolwich system of ordnance. The opposition of the friends of the latter system, and the expense of making a change, have, however, prevented an extended trial of the Whitworth system by the British navy or army.

From what has been stated above, it will be seen that the later vessels of the British navy are exceedingly formidable craft, and that navy, taken as a whole, although not as effective as it was intended by the Admiralty to be, is by far the largest and most powerful navy in the world. In the constructor's department of the Admiralty, Mr. E. J. Reed has left designs for turret iron clads which are calculated to carry 18 inches solid armor upon their sides and 20 inches on their turrets. Such vessels could not be built in the United States until after the expenditure of millions of

dollars in building rolling mills and iron-ship yards, and unless legislation soon causes a commencement, we shall fall hopelessly behind foreign nations in the effectiveness of our navy.

The British government are not so well satisfied with the condition of its navy as to suspend all action towards its further extension, but continue to increase and strengthen it systematically. They propose to add 20,000 tons of iron clad ships yearly to its force, besides transports and unarmored vessels. By her far-sighted policy of liberally subsidizing her lines of steam communication with foreign ports, Great Britain has also almost monopolized the profit derived from the carrying trade of the world in time of peace, and, at the same time, has secured the immense advantage of being able to recruit her navy, in time of war, from the large body of fine officers and seamen, and with the fleet steamers of a wonderfully expanded mercantile marine.

Should no change take place in the policies of Great Britain and the United States, in regard to sustaining and increasing their respective navies, a contrast, most unfavorable to our own country, will soon be presented. Great Britain cherishes her navy with jealous care, and takes advantage of every improvement in construction that science and art can suggest; the navy of the United States, on the other hand, is rapidly losing its efficiency by the decay of its vessels, both of wood and iron, while, in spite of repeated appeals from the Navy Department and from citizens and officials abroad, no action has yet been taken by Congress toward repairing losses or making our naval power commensurate with that of the more important European nations, or toward the re-establishment of a merchant navy which shall become a source of profit in time of peace and an insurance against losses by war. In the event of a foreign war, we may yet find ourselves compelled to call in our ships to defend our harbors, and to remain absolutely powerless for offence.

In the manufacture of steam engines, other than marine, there is, perhaps, not very much that is novel to attract the attention of an American engineer, but he may still find it profitable to spend some time among the English engine building establishments, observing their methods rather than studying designs.

In building *portable* engines, several firms have obtained remarkable economical results.

The favorite style of portable engine is mounted on its boiler, as

is usual with our own builders, but it is almost invariably provided with a steam jacketted cylinder and an independent expansion valve, riding on the back of the main valves, of which there is one at each end of the cylinder, in order to obtain the least possible amount of clearance space.

The style of design and character of workmanship are good, but the engines are invariably free from all attempt at ornamentation; neatness, strength, economy and convenience are the qualities sought by the leading firms.

The following are results obtained at the trial of engines which took place in July last, at the Oxford Agricultural Fair:

Makers' Name and Residence	No. and diameter, cylinders.	Stroke.	H. P.		Point cut-off.	Rev. per minute.	Lbs. coal per H. P. per hour.
			Nom.	Dynamom.			
Clayton, Shuttleworth & Co., Lincoln	1—7″	12″	4	4·42		121·65	3·73
Brown & May, Devizes	1—$7\frac{3}{16}$″	12″	4	4·19	$\frac{11}{14}$	125·65	4·44
Reading Iron Works Co., Reading	1—$5\frac{3}{4}$″	14″	4	4·16		145·7	4·65
Marshall & Sons, Gainsborough,	1—$7\frac{1}{4}$″	12″	4	4·51	$\frac{1}{3}$	124·	5·75

These were horizontal engines, attached to locomotive boilers.

The following are particulars of another set of horizontal engines of larger size, detached from their boilers, and all supplied with steam from a boiler furnished for the purpose by the managers of the show.*

These were the best engines exhibited, and the results are, of course, better than would be obtained in regular working, but they are unusually good, and even remarkable, for engines of such small size.

At a similar exhibition held at Bury, England, in 1867, considerably better results even than these were reported from engines of similar sizes and styles.

* Full particulars of these trials may be obtained by reference to the last volume of the London *Engineering*, a periodical, it may not be out of place to remark, which well represents the most advanced principles and practice of British engineering, and which is always ready to accord the credit due to American engineering.

Makers' Name and Residence	No. and diameter, cylinders	Stroke.	H. P.		Point cut off.	Rev. per minute.	Lbs. coal per H.P. per hour.
			Nom	Dyna-mom.			
Clayton, Shuttleworth & Co., Lincoln	1—10″	20″	10	11·	$\frac{3}{10}$	71·5	4·13
Reading Iron Works Co., Reading	1— $8\frac{5}{8}$″	20′	10	10·43	$\frac{1}{4}$	109·4	4·22
Marshall & Sons, Gainsborough,	1—$10\frac{1}{4}$″	16″	10	10·38	$\frac{2}{10}$	72·7	5·2

With all of these engines steam jackets were used, the feed water was highly and uniformly heated by exhaust steam, the coal was selected, finely broken and thrown on the fire with the greatest care, the velocity of the engines, the steam pressure and the amount of feed water were very carefully regulated, and all bearings were run quite loose; the engine drivers were usually expert "jockeys."

In the manufacture of larger stationary engines, British practice is in an unsettled state; the compound engine has been recently introduced where considerable power is required, but a strong tendency exists to copy from American practice.

The Corliss engine, which has been familiar to American engineers for nearly a quarter of a century, has been adopted by several builders; the Allen engine, which has been well and fully described in recent numbers of this *Journal*, is constructed by the well known Whitworth Manufacturing Company, at Manchesser. Messrs. Towle & Harding, two enterprising American engineers, are introducing the Babcock & Wilcox engine, which has been so highly commended at home for its ingenious combination of theoretical and practical requisites for economy, strength and endurance. It is to be regretted that the Greene engine, another American design, whose simplicity and effectiveness would highly recommend it in the British markets, has no one specially interested in urging its claims there.

The most usual form of stationary engine is horizontal, steam jacketted, with separate valves covering short steam ports at each end of the cylinder, and separate cut-off valves, very similar, in principle, to the Meyer expansion valve. Regulation is generally

effected by attaching the regulator to a valve in the steam pipe, but sometimes, the American idea of determining the point of cut off by the regulator is adopted. American engineers have been more successful than the British in securing small clearance, prompt closing of the cut-off valve, and in attaching the regulator to the expansion valve, while the latter exhibit a much better appreciation of the economical value of the steam jacket where high steam and great expansion are adopted. In both countries another requisite for economical practice—high piston speed—is gradually becoming fully recognized.

One of the most interesting examples in this department of transatlantic engineering is found in the engines of Messrs. A. M. Perkins & Son, of London. This firm, which was founded by an American, is guaranteeing a consumption of less than two pounds of best coal per horse-power per hour with their mill engines, and claim, in some cases, to have brought the figure as low as one pound. These engines are of a peculiar form of "compound engine," the cylinders steam jacketted and vertical, the valve stems *rotating*, with their stuffing boxes placed at the ends of long shells surrounding the stems, the intention of the arrangement being to avoid burning the packing. Surface condensers are used and the feed returned to the boiler at the boiling temperature. The steam is cut off at an early point in the stroke by an independent cut-off valve. The boilers are composed of lap welded tubes, 3 or 4 inches diameter and $\frac{3}{8}$ to $\frac{1}{2}$ inch thick, and are tested to 2500 or 3000 pounds per square inch. Where the condenser supplies an insufficient amount of feed water, the residue is furnished by a still. Steam is carried at from 250 pounds per square inch upward, the safety-valve on Messrs. Perkins' own boiler being weighted to 600 pounds per square inch.

One practice of this firm is worthy of imitation by builders generally. They insure owners of machinery supplied by them against loss by accident, and make all repairs for five per cent. per annum.

In the manufacture of stationary *boilers* the practice is not, on the whole, far different from our own. Occasionally boilers are seen with flues strengthened as described in the previous paper; now and then a boiler is met with having lap welded seams, and at least one manufacturer finds a sufficient number of intelligent patrons to afford him a market for a thoroughly well built boiler, its seams all machine rivetted, the edges of the plates neatly planed to

the proper bevel for caulking, and with all rivet holes *drilled* in place. Machine rivetting is, however, practiced by nearly all boiler makers.

The system of careful and intelligent examination pursued by the several British boiler inspection and insurance companies has done a vast amount of good, by showing that every case of boiler explosion is to be attributed to some simple cause—to faulty design, faulty material, carelessness in attendants, or to the use of badly corroded and worn out boilers. They have completely destroyed all of those far fetched theories which are so frequently proposed by believers in concealed or mysterious causes.

These companies have also been of use in assisting makers in finding a market for well designed and well built boilers, and it is be hoped that, as a similar organization has been started in the United States, equally valuable results may follow its successful operation.

In building *pumping* engines, the tendency seems to be decidedly in favor of throwing aside the cumbersome and costly Cornish engine, and adopting other forms of engine lighter, cheaper and more manageable, as well as of equal and often superior economical performance.

The favorite pumping engine, particularly in London, and where fuel is costly, seems to be a plain beam and crank engine, with a pump of the "bucket and plunger" class, and their performance will probably average 650,000 foot-pounds per pound of Welsh coal. Recently, some "*compound*" pumping engines have been built. The Berlin Water Works engine, completed some months ago by Simpson & Co., of Pimlico, is now reported to have done a duty, on trial, of 1,004,000 foot-pounds per pound of best Welsh coal, working up to 115 H. P. each, and expanding ten times. Such engines are, of course, more expensive than the former style, but their economy more than compensates for the difference in first cost, and when compared with Cornish engines, their first cost is less.

Their economy is, of course, principally due to the greater pressures and greater expansion with which they may be steadily worked. In pumping, as in marine engines, but for different reasons, a regular motion cannot well be secured with high steam and short cut off by the action of a fly wheel, and the compound engine seems to be considered the most promising resource, in this case, in the strife for highest economy of fuel.

The boilers furnished with pumping engines are usually either the single-flued Cornish or the ordinary two-flued internally fired boiler.

British machinery—with now, perhaps, the exception of marine engines—is generally characterized more by strength and durability than American, the endeavor being to obtain a substantial machine rather than one of low first cost. This difference may be probably quite as largely due to the difference in wealth and the distribution

of capital in the two countries as to a difference in the character of their engineers and mechanics.

Less ingenuity is perceived in matters of detail than in America, and we notice particularly the great lack of those little contrivances which, with us, are everywhere found contributing very largely, in the aggregate, to our comfort and convenience, to our safety, and to the economy of manual labor; but it is not unlikely that the cause of this apparent deficiency in invention may be found in an unfortunate system of patent law. In America, any mechanic who originates a useful invention readily obtains a patent, and this patent is a guarantee of his right as inventor, unless proved defective in the courts; in Great Britain, on the contrary, the cost of a patent is so great that few inventors are able to bear the expense of obtaining it and of introducing their inventions, and a patent, when obtained, has really no value as evidence of novelty. We find, therefore, invention encouraged in the United States by complete and inexpensive protection, while it is discouraged in Great Britain by the heavy expense incurred in its simple registration. The material interests of Great Britain certainly demand a change of her patent laws.

NOTE.—We are indebted to the kindness of Mr. J. Jenkinson. U. S. Consul at Glasgow, for statistics just received of the shipbuilding on the Clyde during the year 1870, and other valuable information. We extract the following SUMMARY of work to the close of the year:

	1868.		1869.		1870.	
	Ves'ls.	Tons.	Ves'ls.	Tons.	Ves'ls	Tons.
War vessels	8	5,384	3	9,100	1	2,640
Paddle Steamers—						
Iron	18	6,291	11	6,500	18	9,400
Composite	...	.....	4	1,800	2	750
Screw Steamers—						
Iron	78	78,359	88	81,800	119	132,530
Composite	4	2,882	8	3,800	2	460
Sailing Vessels—						
Iron	73	63,799	78	71,600	40	30,030
Composite	16	13,313	16	16,150	6	6,100
Wood	14	2,231	10	1,400	16	2,740
Yachts	6	331	10	750	8	450
Barges	8	1,900	10	1,000	20	3,700
Dredgers	2	485	2	100	2	1,000
	227	174,978	240	194,000	234	189,800

U. S. Naval Academy, Annapolis, Md., Jan. 21, 1871.

CORNISH ENGINES.

By W. H. G. West, U. S. N.

At this great distance from home I have had the pleasure of reading Mr. Henderson's and Mr. Birkinbine's papers, March and April, 1870, and of finding in them the final necessary evidence in favor of reasons for the superiority of the Cornish engine, advanced in my paper of October, 1868.

With the permission of the Editors, I will reply to them at the same time, and, as nearly as I can, in the order in which they are written.

I beg the readers of the *Journal* to carefully refer to the last named paper, and to that published by Mr. Henderson in the July number of 1868, so that, in reviewing the evidence already produced, there may be no doubt as to the "original question" referred to by Mr. Henderson in his last paper, March, 1870, page 159.

The *original question* was, and is, not *whether* Cornish engines did better duty than any other type of engine or not, but *why* they did it. The first and last paragraphs of Mr. Henderson's first paper, July, 1868, show it. The first and last paragraphs of my first paper, October, 1868, state it distinctly. At Mr. Henderson's request, we will return to the "original question."

Knowing well that simple argument seldom produces good effects, I have waited patiently for the time when Mr. Henderson and his supporters should make such statements as would clearly prove me correct, and that builders neglecting the principles referred to in my paper of October, 1868, could only make a good Cornish engine by accident.

My desire is, and has been, to improve the manufacture of Cornish engines in the United States, and my first paper was the offspring of that desire.

It has been observed that the "classified points of merit" set forth in Mr. Henderson's first paper are supposed to be explanatory of the causes of superiority of the Cornish engine over those of other types, but not one of these "points of merit" shows why one Cornish engine does a duty of 130,000,000, and another too far below 40,000,000 to be mentioned. What, then, causes this difference of more than 90,000,000? Not a paper written upon the subject has drawn attention to this incontrovertible fact, a fact

which goes farther to prove me correct than all that has been written.

The reasons given by Mr. Henderson—the high degree of expansion; the unfettered state of the piston; the saving of steam from loss by clearance; the isolation of the working end of the steam cylinder from the cooling influence of the condenser; the turning to direct account of the *vis viva;* the use of the steam jacket; the inelastic load—are all common to both engines, and yet one does a duty of 130,000,000, while the other does less than an ordinary high pressure engine; one of the generally acknowledged worst type.

I am especially grateful to Mr. Birkinbine for bringing this instance to light. I have been waiting for it. As he says on page 111, August, 1869, it illustrates "defects in construction." It is a Cornish engine, one of the infallibles, but owing to bad construction, and, in all probability, worse design, it is less economical than one of the worst type.

Some of the causes enumerated in my first and second papers were first observed by Mr. William West, the designer of the Fowey Consols engine, and these observations led to many of the improvements in proportions, which finally resulted in the 130,000,000 duty.

The designer of the Easton engine can, I believe, build a much better one, and can, with his own choice of attendants, make the Easton engine do better duty. He certainly would never leave the boilers out in the cold; he would never pass a palpable, or even a possible leak; he would use packing of the best quality, and lubricating matter of the proper nature and consistency; but he would never say that his engine would do better if he had not neglected some of the oldest known causes of superiority, nor would he rule out the perfectly proportioned Fowey Consols engine, because being, perhaps, heavier, it could make use of a higher grade of expansion, or because the water in his case was less elastic than in the case of the Fowey Consols engine. See elastic load, page 159, March, 1870, and page 240, April, 1870.

Elastic load has little or no effect on duty, but supposing it does account for the high duty performed by the rotative engines reported in my paper, it cannot account for the difference, in duty, between the Fowey Consols and Mr. Birkinbine's Canal Cornish engine, page 243, April, 1870, nor for a similar difference between

the Easton engine, doing 94,000,000, and the canal engine, doing too little to be reported. I have a much better right to claim that the Cornish engine does better duty because the load is *not* elastic.

Sea water is not particularly springy; indeed, it is very much like other water in that respect. The propellers of steamships work in this water, and, in the cases I have given, the propeller shafts are of about 18 inches diameter. The elasticity of sea water is no greater than that of mine water. The spring of a large propeller shaft is inappreciable, especially in fine weather, while the spring of pump rods, beams, etc, pumping through a height of 2400 feet, (Fowey Consols is somewhat deeper,) is unavoidable, and comparatively great. The moment a ship commences to spring, the engines get out of line; the journals bind and often cut; the friction is increased inversely; and—where is the advantage derived from elasticity? A stiff, unyielding ship is a blessing to the marine engineer.

Some engines lifting inelastic loads burn 8 to 10 pounds of coal per horse-power per hour, while others burn less than 2 pounds. The same thing occurs with elastic loads. All those lifting elastic loads should beat those lifting inelastic loads, but the contrary is generally the case, as shown by the Cornish engine.

Mr. Henderson finds fault with Mr. Fulton for recommending *economy in machinery*, page 153, March, 1870. He should remember that small cost does not create bad design; that it takes no more time to design an engine of good proportion than one of bad proportion, and I assure him that the Easton engine is one of the cheapest Cornish engines ever built in America.

No Cornish engines that I have ever seen, or heard of, in any country, are provided with bed-plates. The cylinders, air-pump beams aud pump work are entirely unconnected, except by the general stone foundation. No piece of iron, serving as a bed plate, reaches from one of these parts to another. Cornish engineers consider bed plates unnecessary appendages to well designed Cornish engines.

One of the highest recommendations of the Belmont engines is that brought forward by Mr. Henderson as a fault, page 153. The unnecessary outlay of money for the purchase of brass for glands, air-pump buckets, etc., is done away with. The veneering referred to by Mr. Henderson is added to the cheaper metal, for the purpose of preserving smooth surfaces, for packing, etc., to slide upon. The

water that the inhabitants of a city are to drink should not impair the strength of iron by corrosion. Pure water, without air, will not injure iron in years, even to the extent of producing a slight rust. With air it rusts bright iron very slowly. If water contains sufficient acid to corrode glands entirely separated from this water, how much more must it corrode all the pumping apparatus, pipes, valves, air pump, condenser, cylinder, etc. The whole apparatus should, therefore, be made of brass, and who would be simple enough to employ engineers who recommend such an absurdly unnecessary outlay? All this veneering may be found in the Easton engine. I do not wonder that cheap machinery is popular.

Mr. Henderson next brings forward the fact that the four foundation bolts of a 50-inch cylinder are made of $1\frac{1}{8}$-inch iron, and yet he generously sets up the productions of the designer (I do not know the name), who cannot compute the diameter of a bolt, to represent the work of American engineers before the readers of the *Journal.*

On page 154, Mr. Henderson asks why the examples given by him are not acceptable. He may read his own answer on pages 156 and 157 of March, 1870, where he says that the reports of other engineers "amount to nothing," and that "there is no limit to the artifices employed by them to carry out their designs." Almost two pages, 156 and 157, are devoted to arguments against the integrity of these gentlemen, and still he asks why his examples are not acceptable.

On page 156 Mr. Henderson says that "it is not the *custom* to estimate the duty of pumping engines by the amount of *combustible element consumed,* deducting ashes, clinkers, etc.," and, farther on, that "the whole of the coal purchased, and not seen about the works," should be charged. Mr. Henderson's *custom* needs prompt and decided reformation. On this coast I have seen bituminous coal (Welsh—the same kind as that used in Cornwall) containing less than three per cent. of refuse. I have also seen anthracite coal on this coast containing over thirty per cent. of refuse. I have seen bituminous coal, the ashes of which were burnt over and over, leaving no refuse but clinker, and I have seen scores of tons of fine anthracite which could not be burned at all in the ordinary Cornish boiler. Yet this coal was mixed with some of a better quality and sold, costing at the time of consumption about $25 per ton. Anthracite coal always contains this worthless slack. The slack of

bituminous coal is nearly as good as lump coal. Mr. Henderson's "custom" would lead us to expect as good results from a ton of miserable slaty coal as from a ton of the best bituminous.

The cost of fuel has nothing to do with duty. The price of fire wood in London is very much greater than it is in our forests, but the steaming qualities of our pitch pine are much better than those of the fire wood used in London. Coal is cheap in and near the mine from which it is taken, while it is expensive in the large city.

The custom of comparing duties without regard to quality of coal is indubitably wrong, but the amount of combustible contained shows very nearly the real value of the coal, as far as duty is concerned. The cost shows this only in a small degree; it is rather an exponent of the difficulties met with in mining, and the distance between mine and market.

Mr. Henderson lauds the Cleveland engines burning *bituminous* coal and doing 50,000,000 duty. I respectfully refer our readers to his report of the Easton engine, which shows, for it, a duty of 94,000,000, burning rather *fine anthracite* coal.

The duty done by the Cleveland engines is not good, but, on the contrary, under the average given by all the papers lately published in the *Journal*. If they had different cylinders, boilers, pumps, etc., if they were altogether different engines, they might do better duty; but these engines, as designed and erected, have done rather badly. They have done 44,000,000 less than the Easton engine, by Mr. Henderson's own showing, and yet Mr. Henderson says they are among the most economical.

It is true that, as remarked on page 157, March, 1870, the Cornish engine has "emerged triumphant" from comparisons, but I have some fear that no Cornish engines, built upon the principles which Mr. Henderson and his supporters advocate, have passed under the triumphal arch, nor do I think they will while every cause is neglected which goes to make one engine better than another of the same kind, or indeed of any kind. If they are good, why can we not get at the duties?

Why will Mr. Henderson continue to facetiously refer to the benefits derived from the upright manner in which gravity works or acts (page 158), while Mr. Birkinbine so firmly keeps the Canal Cornish engine before his eyes? It ruins his elastic argument, his gravitation argument, and indeed every other that has been advanced on his side.

I cannot accede to Mr. Henderson's request, on page 159, to produce the results of some of my favorite engines pumping water. If I have a favorite—I have no patents—it is the Cornish engine, but it must be a good one. The mails are too irregular, and I am too far from home, to gather statistics. Were I to make the attempt, it would probably be a failure, as Mr. Henderson and Mr. Birkinbine assure me that "there is no limit to the artifices," etc., page 157, March, 1870, and that "these two instances show the unreliability of some claimed duties," April, 1870.

I am perfectly willing to accept, as true, all the statistics given over the signatures of gentlemen writing for the *Journal*, but I cannot help contrasting the above quotations with Mr. Henderson's question, page 154, "why are these examples not acceptable?" and with Mr. Birkinbine's statement that his Bull engines have done 67,000,000. I would strongly urge the acceptance of a mean of all the statements, as premises on which to work.

I am given to understand that Wolf's double cylinder invention was first applied to the Cornish engine, or at least to a pumping engine built in Cornwall.

With the permission of the Editors, I will now reply to Mr. Birkinbine, in the hope that he, too, will see why some engines are wonderfully good—regardless of type or *elasticity* of *load*—while others are disgracefully bad.

Mr. Birkinbine's statements and examples have already helped me to prove that elasticity of load has nothing whatever to do with duty. Were it so favorable to rotative engines as to rule them out of comparison altogether, non-elasticity of load should put the Cornish Engine so far down as to be ruled out also. Our rotative engines were bad to begin with, they are now among the best. Our Cornish engines were very bad to begin with, they are now worse. No weighty, expansive or elastic reasons can disestablish that fact.

Mr. Birkinbine does not appear to know what "the question under discussion" is. I would inform him that it is the "original question" spoken of by Mr. Henderson, and referred to in the early part of this paper.

Mr. Birkinbine has had the misfortune to make a mistake, just a little bit funny, in putting the duties of the Fowey Consols engine Rowan's so close together on his first page. He does not appear to know that Rowan's engine was a *rotative* engine, brought forward in one of my papers to make the best Cornish engine a second rate,

in answer to a request published by Mr. Henderson in December, 1868.

The readers of the *Journal* will do well to compare the next two paragraphs (4 and 5) page 240, with the statement which Mr. Birkinbine makes in regard to the duty of his engines, 67,000,000.

In the last paragraph of page 240, Mr. Birkinbine presents my views, exactly, in regard to the reasons why pumping engines are, in many instances, bad, and it is one of the best explanations given, of the difference between duties of two Cornish engines, or, indeed, any other engines, in the proportion of 67 to 94, or to 130.

I must say of unwillingness to pay for proper machinery, that the same thing occurs in all branches of trade, but when business men order Cornish engines, (and who else does order them?) they expect to pay a fair price. Bad machinery is, as Mr. Birkinbine says, in other words, on page 240, last paragraph, the work of men deficient in engineering knowledge. The price has nothing to do with the design. The completion of a correct design costs less than a series of mistakes resulting in a failure. The Easton engine was well designed; the material employed in the manufacture was fair; the construction or execution of the design—including work of mechanics—was fair, and the *finish* was execrable. The money saved from "finish" was spent in material and good fitting. The price was very small, and the duty 94,000,000; the highest done in America by any pumping engine.

(To be continued.)

WATER WORKS FOR THE PEOPLE.

By W. M. Henderson, Hydraulic Engineer.

An abundant supply of pure and wholesome water, at an economical rate, is every where one of the first requisites of the people, and yet there are, at the present time, numbers of cities and large towns in this country where such a supply is unprovided. It is especially essential both as a beneficial sanitary measure in connection with the health, cleanliness, and comfort of a community, as well as a powerful incentive to encourage the various branches of industry to settle where this all important element is to be found. In addition to the requirements for household purposes, there are other demands, embracing mercantile necessities, as the supplying of steam boilers with water, and the numerous purposes required by factories of the different kinds; while, if the supply

will permit, there are plenty of other uses to which water can be applied with manifest advantage, as the cleansing of streets from the accumulation of offensive matters, the purifying and cooling of the air, in the hot summer months, by copious distributions used in the washing of pavements, sprinkling of streets, lawns and gardens, supplying fountains, and in many other ways contributing to the beauty and attractiveness of the city or town happily furnished with this truly health-giving medium.

As the population increases, other requirements present themselves where water is of the very utmost importance. Conflagrations will occur, more or less disastrous, frequently laying waste whole sections of cities, spreading fear, consternation and ruin on every hand, accompanied too often with fatal results.

How important, then, is this question of the abundant and reliable supply of water! And when we consider how easily this great boon can be acquired, how culpable are they who, placed in authority to administer to the wants of the people, yet neglect this most serious duty. It is not even an expensive luxury, for there is no better investment to be found for that surplus capital, existing in all thriving communities, than this producing of *water works for the people.* They are at once a source of revenue, being self-maintaining by the collections arising from water rents, fully adequate, by proper management, to pay a liberal interest upon the investment, and to rapidly create a sinking fund to pay off the original outlay. Apart from all this, they will be found to repay many times their cost, in the matter of reduction of insurance rates, and the saving effected in regard to property, which would otherwise have been destroyed. They also enhance the value of this property, as has been found to be the invariable case wherever they have been introduced.

The primary step to be taken, when it has been decided to have water introduced into a town, is to ascertain, by a general survey of the immediate neighborhood, whence a quantity, adequate to the necessities of the inhabitants, can be procured. It should be determined beyond doubt that this source shall be amply sufficient to furnish, at all times, the amount absolutely required, even in seasons of drought—for once the people have been led to depend upon a regular supply the former means will have been abandoned, passed away and beyond the reach of being again made servicable. These preliminaries having been satisfactorily settled upon, the question of preference in regard to the system to be adopted for distributing the supply, is purely one of a pecuniary character. The various plans upon which water works have been successfully constructed, will be found to be embraced under the following heads:—

Water Supply with Reservoir—Water Supply with Standpipe—and Direct Water Supply.

1*st. Water Supply with Reservoir.*

This is the oldest of the methods here described for supplying cities with water, and for many reasons it is the best; at the same time it is the most expensive. But where enconomy of first cost is not considered the paramount object to be obtained, it will be found to be the cheapest in the end. The manifest advantage of the reservoir system is to be found in the storing up of a large body of water, to be made available in time of drought, or in case of interruption by accident to any part of the pumping machinery. The reservoir maintains a constant head upon the mains, by virtue of simple hydrostatic pressure. And it also serves as a repository for any impurities the water may hold in suspension, which settle to the bottom, the pure water being withdrawn from a few feet above. Another great advantage of the reservoir is, that the pumping can be effected within certain limits of time—say half time running; thus affording ample opportunity for keeping the machinery in proper working order, as well as giving the engineer in charge facilities for a general inspection of the works, with a view to repairs, or contemplated additions and improvements.

The proper carrying out the benefits to be derived from this system necessitates the use of a distinct distributing main, though it not unfrequently happens the delivery main from the pump is made to serve the double purpose. The value of the reservoir system was fully exemplified to the citizens of Philadelphia during the drought of 1869. Had it not been for the *Reservoirs*, the suffering of the people must have been calamitous.

2*d. Water Supply with Standpipe.*

This in order is the next method for maintaining a uniform pressure upon the street mains. The water from the pump rises within the standpipe to an elevation corresponding, in effect, the same as if a reservoir of a similar altitude were employed. The irregularities produced by the action of the pumps are here equalized, and the stream caused to flow in a steady current. It is apparent the quantity of water capable of being contained in the standpipe is a very limited amount, consequently no prolonged stoppage of the machinery can be indulged in, although it will afford sufficient time for repacking the engines, and other ordinary adjustments. Some of the water works in and around Philadelphia, have, in times past, supplied their water by the aid of the stand pipe, varying from 130 to 170 feet in height. At Erie, Pa., there is one of 217 feet high—said to be the highest in the world. As an expedient to overcome the expense attending the building of a reservoir, the stand pipe has been found to answer remarkably well.

Of course the water will be delivered with all the impurities it may hold in suspension, but if the water to be pumped is first received in a subsidary reservoir, filter-bed, or carefully constructed wells, according to the plans usually pursued in such cases, water can, without doubt, be furnished of a pure and wholesome character.

The proper carrying out of this system involves the necessity of duplicate machinery and double set of hands to insure a supply of water, for it would be impossible to guarantee a single pumping engine against accidental derangement at some time which would be fatal, as will be readily perceived.

3d. Direct Water Supply without Reservoir or Standpipe.

The idea of dispensing with all auxiliary receptacles for retaining any mass of water, and pumping directly through the mains to the consumers, was, it is believed, first introduced in London, in the year 1582, where was erected, at London Bridge, a water wheel, driving four gang piston pumps, arranged to take water alternately, which at that time created quite a sensation. The machinery, it is related, was found, upon trial, to be very effective, furnishing a good supply of water to the city, and had the capacity of throwing streams of water over St. Magnus steeple. The growing wants of the city, impurity of the water, and other reasons, combined to its abandonment fully a century ago. Quite lately this identical system has been reproduced in this country, the firm now building upon this plan claiming to have originated it, and lauding it above every thing else for water work purposes. In addition to the gang pumps, the American inventor has introduced the extraordinary combination of *rotary pumps*, and where steam is to be substituted for water power, *rotary engines* also—two of the most wasteful forms, for the purpose, which the ingenuity of man could well devise. There are many situations and attending circumstances where the direct supply system can be employed with advantage. But that is the *ne plus ultra*, for all and every rotation is a plain misrepresentation of facts. That which immediately recommends it is the comparatively small outlay required to erect works upon this plan. A standpipe or reservoir can afterwards be added, when the necessary capital has been raised. It is not imperatively necessary, however, to employ a gang of small pumps, interspersed, by way of variety, with one or more upon the *rotary principle*; nor is it likely to be conducive to economy to employ, as a motor, a steam fan, or, as it is commonly called, a *rotary engine*, to produce the simple results aimed at. Indeed there is little occasion to depart from the usual description of machinery, perfected by long usage to the requirements of water work purposes. The all-absorbing question of economy in regard to fuel and repairs, is a powerful argument against the *rapid reciprocation* of short stroke gang pumps, and the ruinous effects produced by that *high velocity* demanded by the rotary principle. Economy in any form, under such circumstances, is entirely out of

the question; for so long as the laws which govern the universe are in force, that which was established at one period of time will still remain a fact in all succeeding ages, and no amount of controversy, or opinions of any set of men, advanced as a species of special advocacy, have the power of setting it aside. *The true expense of an engine is the original price, added to its annual cost for maintainance, capitalized say at* 20 *years' purchase.* The direct supply system dispenses with the cost of constructing reservoirs, to which extent it will be more economical in the first instance. But it is less regular than either of the others. The machinery is required to be kept in motion all the time, or at least ready to start at any moment when water is wanted. Vigilance is an incessant and arbitrary requirement. A fire may break out any instant of time, night or day, and may not occur for months; still the price of security is eternal vigilance, which in the case where steam is employed as a motive power, means continuous consumption of fuel; which again, in plain English, means wasting money. In connection with this system, it must not be forgotten that all the connections pertaining to the distributing mains require to be made especially heavy, and consequently more than usually expensive, with a view to withstand the excessive pressures thrown upon them when the engines are forcing against the enormous pressure necessary to be effectual in case of *fire.* It becomes quite a serious question, then, whether it is altogether satisfactory or judicious to assume this extra cost, together with the risk of leaking joints and bursting pipes, from the cause pointed out, for the mere sake of dispensing with that portable fire apparatus so well known throughout the country.

BELTING FACTS AND FIGURES.

By J. H. Cooper.

(Continued from page 109.)

Friction Wheels.—"Wheels acting upon each other are the instruments by which the transmission of force from one part of a system of machinery to another is commonly and conveniently effected. The due connection of the moving parts is accomplished either by the mutual action of properly formed teeth, by straps or endless bands, or by the friction of one face of a wheel against another. The latter method has, when, adopted, been generally in small light works, where the pressure upon the different parts of the machinery is never considerable. Nr. Nicholson saw a drawing

of a spinning-wheel for children, at a charity school, in which a large horizontal wheel, with a slip of buff leather glued on its upper surface, near the outer edge, drove 12 spindles, at which the same number of children sat. The spindles had each a small roller likewise faced with leather, and were capable, by an easy and instantaneous motion, of being thrown into contact with the large wheel at pleasure. The winding bobbins for yarns at the cotton mills operate on the same simple and elegant principle, which possesses the advantage of drawing the thread with an equal velocity, whatever may be the quantity on the bobbin, and cannot break it.

"We are not aware that the same mode of communication has been adopted in large works, except in a saw mill, by Mr. Taylor, of Southampton. In this the wheels act upon each other by the contact of the end grain of wood instead of cogs. The whole makes very little noise, and wears very well; it has now been in use nearly twenty years. There is, of consequence, a contrivance to make the wheels bear firmly against each other, by wedges at the sockets, or by levers. This principle and method of transmitting power certainly deserves every attention; particularly as the customary mode, by means of teeth, requires much skill and care in the execution, and, after all, wants frequent repairs."—*Treatise on Mechanics. Olinthus Gregory: London*, 1806.

From *Rankine's Manual of Machinery and Mill Work* we take the following:

"The flexible pieces used in machinery may be classed under three heads: *Cords*, which approximate to a round form in section; *Belts*, which are flat; and *Chains*, which consist of a series of rigid links, so connected together that the chain, as a whole, is flexible. Mr. Willis gives them all the common name of *wrapping connectors;* and for the sake of brevity in stating principles that apply to them all, they may conveniently be called *bands.*

"The *effective radius* of a pulley is equal to the radius of the pulley added to half the thickness of the band.

"Smooth bands, such as belts and cords, are not suited to communicate a velocity-ratio *with precision*, as teeth are, because of their being free to slip on the pulleys; but the freedom to slip is advantageous in swift and powerful machinery, because of its preventing the shocks which take place when mechanism which is at rest is suddenly *thrown into gear*, or put in connection with the prime mover. A band at a certain tension is not capable of exerting more

than a certain definite force upon a pulley over which it passes, and therefore occupies, in communicating its own speed to the rim of that pulley, a certain definite time, depending on the masses that are set in motion along with the pulley and the speed to be impressed upon them, and until that time has elapsed the band has a slipping motion on the pulley; thus avoiding shocks, which consist in the too rapid communication of changes of speed.

"The swell usually allowed in the rims of pulleys is *one twenty-fourth part of the breadth.*

In quarter twist belts, "in order that the belt may remain on the pulleys, *the central plane of each pulley must pass through the point of delivery of the other pulley.* It is easy to see that this arrangement does not admit of reversed motion.

"The safe working tension of leather belts, according to Morin, is 285 pounds on the square inch. The ordinary thickness of belting leather is about ·16-inch.

"The inside of the leather is rougher than the outside, and is placed next the pulleys, crossed belts being twisted so as to bring the same side of the leather in contact with both pulleys.

"*Leather belts*, when new, are not quite of the heaviness of water, say 60 pounds per cubic foot; but after having been for some time in use, they become thinner and denser by compression, and are then about as heavy as water. The weight of single belting is approximately ·068 pounds per one inch breadth and one foot length.

"*Raw Hide Belts* have a tenacity about one and a half that of tanned leather. When raw hide is used for belts or for ropes it is soaked with grease, to keep it pliable and protect it against the action of air and moisture.

"*Gutta-Percha* is sometimes used for flat belts. They are made of the same dimensions with leather belts for transmitting the same force, and are nearly of the same weight.

"*Woven Belts* are made of a flaxen or cotton fabric, a sufficient number of plies being used to give a thickness equal to that of leather belts, and cemented together with india rubber. When made of flax, they are said to be about three times more tenacious than tanned leather belts of the same transverse dimensions.

"Ultimate tenacity of leather rope, 10,000 feet, or 3360 pounds on the circular inch; of raw hide, 15,000 feet and 5040 pounds on the circular inch; safe working tension, one-sixth of these dimensions.

"The ordinary speed of wire ropes in Mr. C. F. Hirn's 'Telodynamic Transmission' of power is from 50 to 80 feet per second, and with wrought iron pulleys it is considered that it might be increased to 100 feet per second.

"In order that the rope may not be overstrained by the bending of the wires of which it consists, in passing round the driving and following pulleys, the diameter of each of those pulleys should not be less than 140 times the diameter of the rope, and is sometimes as much as 260 times.

"The distance between the driving and following pulleys is not made less than about 100 feet; for at less distances shafting is more efficient; nor is it made more than 500 feet in one span, because of the great length of the catenary curves in which the rope hangs. When the distance between the driving and following pulleys exceeds 500 feet, the rope is supported at intermediate points by pairs of bearing pulleys, so as to divide the whole distance into intervals of 500 feet, or less.

"The bearing pulleys have half the diameter, and are of similar construction with the driving pulleys.

"The loss of work due to the stiffness of the rope may be regarded as insensible; because, when the diameters of the pulleys are sufficient, the wires of which the rope is made straighten themselves by their own elasticity, after having been bent.

"Experience shows the loss of power by the axle friction of driving and following pulleys to be about $\frac{1}{40}$th, and of the axle friction of each pair of bearing pulleys about $\frac{1}{960}$th of the whole power transmitted."

(To be continued.)

ON THE HORSE-POWER OF STEAM ENGINES AND BOILERS, AND SOME FACTS CONNECTED WITH THE EXPANSION OF STEAM.

By Edward Brown.

[Read before the Franklin Institute at its Stated Meeting in January.]

An actual horse-power, as is well known, is 33,000 pounds raised one foot high per minute. The application of this test to engines and boilers is the subject of this paper.

It has been, and still is, a common custom with steam engine builders, to specify in the contract of sale that the engine and boiler are of a certain size and horse-power. That the machines come up

to the contract in size is easily determined by measurement, but the actual horse-power developed by a steam boiler is a subject upon which the seller and buyer may differ materially.

It is useless for one to attempt to make a standard rule for the horse-power of an engine from the size of the cylinder. An engine 10×24 inches will work from 20 to 100 horse-power, according to the pressure of steam and speed of the piston. The seller might designate whatever power he pleased within these limits; it would be very little guide to the purchaser.

The case is, however, different when we come to estimate the horse-power of an engine and boiler sold as a unit. There will be no question among engineers that here the horse-power, according to common custom and practice, is the power exerted upon the piston, measured by the area of the indicator diagram. If the machine will perform that work steadily, from week to week, such is its actual horse-power.

Let us now examine the means of ascertaining the horse-power of a *steam boiler*, sold, we will say, for 100 horse-power, but failing to come up to the expectation of the purchaser. This is a practical question, and one not unfrequently occurring. Especially is it liable to occur with boilers of the non-explosive patterns, recently introduced. The makers are endeavoring to supply, and the purchasers to obtain, a perfectly safe boiler, of the same horse-power and at the same price as those of the usual standard forms.

Several cases of this character having recently come under my observation, I will give you the course pursued in one of them to ascertain the horse-power of the boiler.

The boilers replaced some old worn out boilers which were removed. They supplied steam to a cylinder 16 inches by 4 feet, speeded for about fifty revolutions. The boilers were fired to the best ability of the fireman, and steam being maintained at forty revolutions, the cards A were taken, showing no expansion and $55\frac{1}{2}$ H. P. It was justly objected by the Boiler Company that this was an extravagant use of the steam, and not a fair test of the H. P. of the boiler. A Tremper cut-off was then fixed on the back of the steam chest, and a trial made a few days afterwards. The steam chest was small, and the space between the cut-off and D valve not over one-tenth the size of the cylinder. The card marked B was then taken showing a cut-off at a little under $\frac{1}{4}$ from the commencement of the stroke, and 68 H. P. with 33 revolutions. It is

a very fair expansion card, the initial pressure being 73 pounds. Though not quite equal to a Corliss, it would be little behind it in economy. The gain in power resulting from the change from full stroke to $\frac{1}{4}$ cut-off is $12\frac{1}{2}$ horse, or 23 per cent., due to the expansion of the steam. But as there was less back pressure in the latter than in the former trial, we have an actual gain of 30 per cent. in the working of the engine. The engine exhausted into a feed-water heater.

Now notice the diagram C. This was taken with more boiler power, 3 being used instead of 2, as in the trial just described. The expansion curve here is formed entirely by the higher speed of the

engine (53 revolutions) and the smallness of the port. The indicated H. P. was 89, and that developed by the Tremper cut-off, marked D, was 100 H. P. Here we have a gain of 12 per cent. only, due to the cut-off and expansion thereby; and a gain of 20 per cent. in the working of the engine. 12 per cent. from 23 per cent. leaves

11 per cent. gain, due to the wire drawing of the steam, as in card C, over that used in the first trial, as shown by card A.

This result tends to prove that it matters little in practice whether the *expansion curve is formed* by the wire drawing through the port and the speed of the piston, or in the usual cut-off manner and low speed; and for this reason, that the action of the steam after it passes the port is almost instantaneous in comparison with the motion of the piston. The cylinder was well curved, though the steam pipe was not; had it been covered, and the cut-off valves close at each end of the cylinder, a little better result would have been obtained. The gain of 23 per cent. here obtained corresponds closely with the experiments of Mr. Isherwood, who gives 26 per cent. as the gain by suppressing during the last $\frac{3}{4}$ of the stroke, and using saturated steam. His experiments also go to show that about 16 out of this 26 per cent. is gained by suppressing during the last $\frac{1}{4}$ of the stroke.

When we consider the vast disproportion between the power which should be gained by cutting off at $\frac{1}{4}$ stroke, theoretically, and that resulting from practice, we may well doubt, as some engineers have done, if there is any gain in the expansion of steam *per se;* and conclude that the gain is due more to the application of the power at the commencement of the stroke, and the complete utilization of it before the termination. An experiment dispelled this supposition. During the dinner hour, when the engine was running the shafting only, the work being therefore constant, diagrams were taken at a speed of 48 revolutions. Four were taken at full stroke, marked E, and three were taken at short cut-off, as shown at F; the average pressure of cards E was 16·3 pounds, and of cards F 16·4 pounds, sufficiently near to be called identically the same. The experiment was carefully made, with the indicator just cleaned and oiled, and the calculated power was 38 H. P. In theory, a pressure of 50 pounds through any part of the stroke would be as effectual as the same pressure through any other part of the stroke, taking no account of momentum. If we take this into consideration, the natural conclusion would be that a preponderating power at the commencement of the stroke, or, in other words, the proper application of the power at the right time, would be more effectual than an even power continued at the end of the stroke. Consequently, the cut-off cards should be smaller, but such was not the case; clearly showing that the gain in power in the previous trials was due to expansion. Of course, the equality of the two cards, E and

F, only refers to this particular engine; it is quite possible that if the experiment was made at 150 revolutions instead of 48, the cut-off cards would be found the smallest. In a trial of this kind the indicator should be changed to each end of the cylinder. The fixing of it in the centre, though frequently adopted for convenience, is not sufficiently accurate.

The bearing these facts have upon the question before us is this, that whilst the horse-power of a boiler depends somewhat upon the engine it supplies, still it is only to a limited extent. That a 3-port D valve engine, in good order, and cutting off at less than $\frac{1}{4}$ from the termination of the stroke, is realizing within 12 per cent. of the power. And even granting that it may be 20 per cent. under what is obtained in the best cut-off engines, a boiler should be able to give out that amount extra in a trial of ten hours, with good coal and careful firing.

Again, purchasers of steam boilers look at the question in a practical way; they do not understand the fine point, as to how much power the evaporation of so much water should produce; they want the power put through their own engine, and as three-quarters of all the steam engines in use are plain slide valve, it is but reasonable to expect that every boiler sold for a certain H. P. shall be able to put that power through a plain slide valve engine, of proper capacity, in good order, and suppressing steam more than $\frac{1}{4}$ of the stroke.

Let us now consider the test by the evaporation of water. A 100-horse boiler may be sold to supply a 50-horse engine, the other 50-horse being required for heating purposes; or the boiler may be needed entirely for heating purposes. Here we must decide by the evaporation, and if the purchaser has not had the foresight to specify the amount, what shall be the test?

We take the old *nominal* H. P., and the evaporation of 1 cubic foot of water is the test. We come down to the theoretical H. P., and 920 inches or 33 pounds is the test. That is to say: theoretically, if you have a cylinder 1 square foot area and 1728 feet high, and evaporate 1 cubic foot of water within that cylinder, in an hour and then condense the steam, it will give a force of 1·88 H. P.

I find on reference to Mr. Isherwood's experiments, that he obtained, occasionally, 1 H. P. from the evaporation of 29 pounds of water, 4 pounds less than the theoretical amount; this can only be accomplished by expansion. With superheated steam he obtained

1 H. P. from 20 pounds of water and an early cut-off. Modern practice has done better than this with the compound engine.

On the other hand, the steam may be overcharged with watery particles, and so show a high evaporation with little power; I have seen $\frac{9}{10}$ths of a cubic foot required to produce a H. P. in a very fair engine, cutting off at the last quarter. So we see that the range is from less than half a cubic foot to $\frac{9}{10}$ths of a foot; the average for good engines being about 40 pounds. It is quite safe to assume that the evaporation of 1 foot of water is abundance for a horse-power, provided the consumption of coal be taken into account; for a small boiler with good draught, burning much coal, will give out as much power as a larger boiler burning less coal. Therefore, the commercial value of a steam boiler, estimated by the H. P., depends upon its ability to evaporate a given amount of water into DRY steam, on a basis of a certain amount of coal, say, about 8 pounds. The conclusion arrived at in reference to this subject would be, that neither the test by the engine nor by evaporation is a positive test. By the engine test, the efficiency of the engine is always liable to be called in question. The steam pipe may be long and contracted, and the pipe and cylinder uncovered, and a large back pressure, for which allowance must be made. The boiler may also be forced for a trial of ten hours, and more coal burnt than usual.

And by the evaporation test it will be found that some boilers are notorious for lifting water; that is, carrying it over bodily. Exceptional cases will always occur in which either test is unsatisfactory; then the only way is to combine the two methods.

It is desirable that the Franklin Institute should establish some standard generally acceptable among engine builders, so that the mill owner, in the purchase of a boiler of a certain H. P., may expect a definite quantity.

Until such is established, it will be for the interest of makers and purchasers of steam power to specify the test by which the power is to be measured.

ON TILGHMAN'S PROCESS OF CUTTING HARD SUBSTANCES.

By Coleman Sellers.

How to cut or carve, mechanically, hard substances, such as stone, glass or hard metals, in an expeditious, accurate and economical manner, has always engaged the attention of engineers. At the present time, the rapidly increasing cost of manual labor makes improvements in this direction more needful. The discovery and utilization of opaque crystallized carbon, cheaper than transparent diamonds, but perhaps equally durable, has gone far in this direction. Now, Mr. B. C. Tilghman, of Philadelphia, comes forward, and shows that a jet of quartz sand thrown against a block of solid corundum will bore a hole through it 1½ inches in diameter, 1½ deep, in 25 minutes, and this with a velocity obtainable, by the use of steam as the propelling power, at a pressure of 300 pounds per square inch—a remarkable result, when we consider that corundum is next to and but little inferior to the diamond in hardness.

At the stated meeting of the Franklin Institute, held February 15th, 1871, the Resident Secretary, Dr. W. H. Wahl, introduced this invention, illustrating his description of it by practically cutting or depolishing the surface of a plate of glass by a sand blast of very moderate intensity. Various examples of hard substances cut, depolished and carved into shape, were displayed. In the discussion which followed the presentation of this very remarkable discovery, Mr. Robert Briggs, in his interesting remarks on the subject, took occasion to say that it had been long remarked that window glass, exposed to the wind driven sand, near the sea shore, soon loses its polish, and cited some other well known examples of the erosion of surface when exposed to a continued stream of moving particles. When we think of the many such examples, and consider that engineers have had continually to make provision against this well known cutting effect, it seems surprising that it should not have been turned to some good account before this.

Mr. Tilghman's attention seems first to have been directed towards cutting stone, or hard metal, by a jet of sand impelled by escaping steam under high pressure. His early experiments were, I believe, with very high pressure, but as he progressed in the knowledge of results obtainable with various velocities, a great use for this process seemed to develop itself in sand driven by moderate air blasts,

and applied to grinding or depolishing glass for ornamental purposes.

For grinding glass he uses a common rotary fan, 30 inches in diameter, making about 1500 revolutions per minute, which gives a blast of air of the pressure of about 4 inches of water, through a vertical tube, 2 feet high by 60 inches long, and 1 inch wide.

Into the top of this tube the sand is fed, and falling into the air current and acquiring velocity from it, is dashed down against the sheets of glass, which are slowly moved across, about 1 inch below the end of the tube. About 10 or 15 seconds exposure to the sand blast is sufficient to completely grind or depolish the surface of ordinary glass; so that sheets of it carried on endless belts may be passed under this 1-inch wide sand shower at the rate of 5 inches forward movement per minute. In the machine in use for this purpose the spent sand is reconveyed to the upper hopper by elevators, and the dust made by the sand blast (which might otherwise be a source of annoyance to the workmen) is drawn back into the fan, and thence passes with the wind into the blast ton, and again mingles with the shower of sand upon the glass.

By covering parts of the glass surface by a stencil or pattern of any tough or elastic material, such as paper, lace, caoutchouc, or oil paint, designs of any kind may be engraved.

There is a kind of colored glass made by having a thin stratum of colored glass melted or "flashed" on one side of an ordinary sheet of clear glass. If a stencil of sufficient toughness is placed on the colored side, and exposed to the sand blast, the pattern can be cut through the colored stratum in from about 4 to 20 minutes, according to its thickness.

The theoretical velocity of a current of air of the pressure of 4 inches of water, he calculates, is (neglecting friction) about 135 feet per second; the actual velocity of the sand is doubtless much less.

If a current of air of less velocity is used, say about 1 inch of water, very delicate materials, such as the green leaves of the fern, will resist a stream of fine sand long enough to allow their outlines to be engraved on glass. By graduating the time of exposure with sufficient nicety, so as to allow the thin parts of the leaves to be partly cut through by the sand, while the thicker central ribs and their branches still resist, the effect of a shaded engraving may be produced.

The grinding of such a hard substance as glass by an agent which

is resisted by such a fragile material as a green leaf, seems at first rather singular. The probable explanation is, that each grain of sand which strikes with its sharp angle on the glass pulverizes an infinitesimal portion which is blown away as dust, while the grains which strike the leaf rebound from its soft elastic surface.

The film of bichromatized gelatin, used as a photographic negative, may be sufficiently thick to allow a picture to be engraved on glass by fine sand, driven by a gentle blast of air.

For cutting stone the inventor uses steam as the impelling jet; the higher the pressure, the greater is the velocity imparted to the sand, and the more rapid its cutting effect.

In using steam of about 100 pounds pressure, the sand is introduced by a central iron tube, about $\frac{3}{10}$-inch bore, while the steam is made to issue from an annular passage surrounding the sand tube.

A certain amount of suction of air is thus produced, which draws the sand through the sand tube into the steam jet, and both are then driven together through a tube about 6 inches long, in which the steam imparts its velocity to the sand, and finally strike on the stone, which is held about an inch distant from the end of tube.

At the spot struck a red light is visible, as if the stone was red hot, though really it is below 212° Fah. The light is probably caused by the breaking up of the crystals of the sand and stone.

The cutting effect is greatest when free escape is allowed for the spent sand and steam. In making a hole of diameter but slightly greater than that of the steam jet, the rebounding steam and sand greatly interfere with and lessen the efficiency of the jet.

Under favorable conditions, using steam which he estimated as equal to about 1½ horse-power, at a pressure of about 125 pounds, the cutting effect per minute was about 1½ cubic inches of granite, or 3 cubic inches of marble, or 10 cubic inches of soft brown sand stone.

By means of flexible or jointed connecting tubes, the blast pipe is made movable in any direction; grooves and mouldings of almost any shape can thus be made, or by means of stencil plates, letters or ornaments can be cut either in relief or intaglio, with great rapidity in the hardest stone.

At a high velocity, quartz sand will cut substances much harder than itself, as before stated. With a steam jet of 300 pounds pressure, a hole 1½ inches in diameter was cut through a piece of corundum, 1½ inch thick, in 25 minutes.

A hole 1 inch long and ¼ inch wide was cut through a hard steel file ¼ inch thick, in 10 minutes, with a jet of 100 pounds steam.

A stream of small lead shot, driven by 50 pounds steam, wore a small hole in a piece of hard quartz; the shot were found to be only very slightly flattened by the blow, showing their velocity to have been moderate.

Among the curious examples of glass cut by this sand blast was shown a piece of ordinary window glass, which, having been partially protected by a covering of wire gauze, had been cut entirely through, thus producing a glass sieve, with openings of about $\frac{1}{12}$th of an inch, the intervening glass meshes being only $\frac{1}{16}$th of an inch wide. This seems to have been produced more as a curiosity than for any practical purpose. Should such a sheet of perforated glass be required, it is questionable if it could be produced for a solid sheet by any other method.

A microscopic examination of the sheet glass depolished by this process shows a succession of pits formed by the blows of the impinging grains of sand, and looks more uniform than do surfaces ground by any rubbing process.

This steam sand jet has already been introduced to clean cast iron hollow ware previous to tinning the interior. Heretofore the interior surface has been turned, it having been found necessary to remove a thin shaving in a lathe to obtain a clean surface. The surface is cleaned more rapidly by the sand blast, and even more perfectly, because it penetrates into any holes or depressions which the turning tool could not reach. It is also probable that the sand striking the particles of plumbago, which separate the particles of metallic iron in ordinary gray cast iron, will remove them, and thus expose a continuous metallic surface to take the tin.

In this relation I might note, that about twenty-five years ago, some experiments were made in Cincinnati, at the establishment of Mr. Miles Greenwood, by my brother, Mr. George Escol Sellers, with a view to making tinned hollow ware of ordinary gray iron. He made a machine for scouring the inside of the pots and kettles with sand and water; afterwards the still wet, scoured surfaces passed into the chloride of zinc solution, and thence into the molten metal, and were uniformly turned. For some reason, the process was not continued, and now it is only recorded as an abandoned invention, never before made public. The wet sand grinding could

not, in this case, have been so efficient as Mr. Tilghman's sand blast. To speculate on the various uses to which this process may be applied, would not serve any good end, and would take up too much space. With this discovery we can hardly help recurring to the works of the ancients, and wondering if some such process could have aided the workers in the stone age, or could have been used in carving the Egyptian hyeroglyphics. It has been noted by those familiar with the cutting or dressing of stone, that some materials, such as granite, is very much injured, or "stunned," by the blows of the cutting tool, and after being hand dressed a thickness of perhaps from $\frac{1}{8}$th inch to $\frac{1}{4}$th inch has to be ground away, to produce a solid uniform surface. By this sand cutting process the surface is not injured, is not "stunned," and is ready for polishing at once.

One curious fact connected with its use is, that when a surface to be cut in intaglio or otherwise is partially protected by templates of metal, these templates curl up under the blows of the sand, so that paper patterns are really more durable than patterns cut from brass. Sheet steel, cut into shape and then hardened, will also curl up under the blows of the fine particles of sand, unless protected by sheets of yielding material. Fine lace will protect glass during the depolishing process, and leave its designs in polished lines on a ground surface.

Artificial Production of Indigo.—In former numbers of this *Journal* we recorded a triumphant achievement for organic chemistry, in the manufacture of alizarine, the coloring principle of the madder root; to this we may now add another, no less in importance than the artificial production of the Indigo blue. The glimpse we are permitted at the dormant possibilities of this marvellously active science, by the two brilliant discoveries so recently made, and here referred to, is perplexing in its infinite variety. In a commercial sense, the discovery is as yet valueless, no time having elapsed for its development with this object in view; but it is too manifestly a mere question of time to need remark. This important discovery is the fruit of the labors of two German chemists, Messrs. Emmerling and Engler. The process of manufacture is a highly complicated one, and altogether of too technical a nature to be here reproduced. The announcement, however, of the fact cannot fail to awake the liveliest interest.

Mechanics, Physics, and Chemistry.

THE SUN.

(A course of five lectures before the Peabody Institute of Baltimore, January, 1870.)

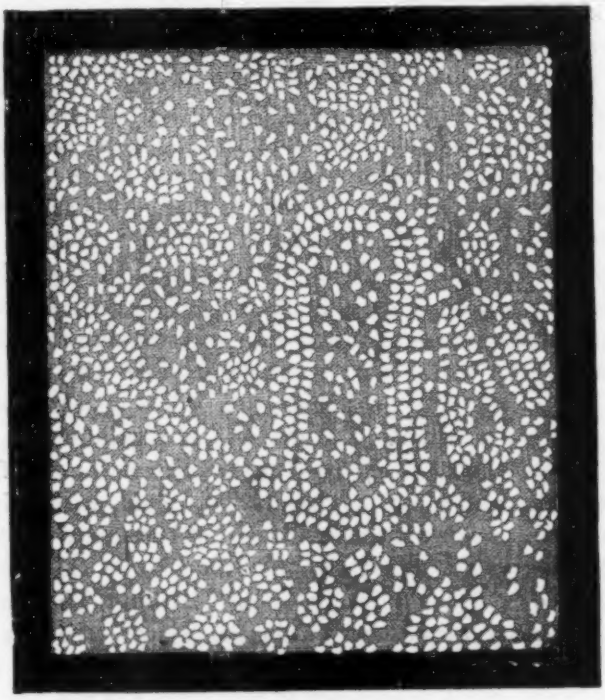
By B. A. Gould.

(Continued from page 137.)

The granules are of various sizes, but may, on the average, be roughly taken as about 1½″ in length and 1″ in breadth, corresponding to about 675 by 450 miles. As seen with a magnifying power of 100 diameters, they may fairly be compared to rice grains, but under higher powers their regularity of form mostly disappears. Some are nearly round, others oval, and others still almost without symmetry of outline. On many parts of the sun they are separated by small dark intervals; except in the penumbra of spots they are rarely superposd; but in many places they are closely aggregated, and give the effect of bright tesselation. These *groups* of aggregated granules are often round or oval, and have unquestionably been often mistaken for single ones. The coarser mottling of the solar disk arises chiefly from the alternation of lines or groups of closely aggregated granules, and of regions in which they are less abundant. The points are the interstices between them, as they appear through a telescope of insufficient power. In a faculæ the granules are aggregated very compactly, while in the penumbra of a spot they are smaller and fainter, although superposed sometimes quite thickly one upon another. Mr. Huggins sums up most admirably, by saying: "The phenomenon would be well represented if we might suppose that the granules are recently condensed incandescent clouds; that they slowly sink, merge into each other, become less and less luminous, and gradually dissipate into comparatively non-luminous gas. The dark pores would then be represented by the portions where complete vaporization had taken place." He also gives an interesting diagram, which is here reproduced, to show the distribution of the bright granules on those parts of the sun which are free from spots, in some of the most characteristic forms of their grouping. There is also some reason to suspect that all the granules may not be of the same brilliancy, although those in any one group closely resemble each other.

Thus it seems established that the luminous surface of the sun is entirely composed of these glowing particles or granules—almost as small as we can discern—notwithstanding that they can scarcely be less than 700 miles in length—floating in a sea of darker, though

Fig. 7.



luminous matter. The brighter and the darker mottlings of the ordinary surface, the brilliant glow of the faculæ, and the dimmed lustre of the penumbra must alike be referred to the intrinsic splendor of individual granules, distributed in different ways, arranged more or less compactly and at different degrees of submergence in the fluid medium which supports them. And Lockyer, a young English astronomer, who has done much within the last three or four years to advance our knowledge of the constitution of the sun, says * that he has seen the granules in the penumbra change their axial direction, and others, visible against the nucleus as a background, gradually melt away. Chacornac, a French observer of distinction, says, moreover, that the granules, or crystals, as he calls them, may be seen dissolving like crystals of sugar before a jet of steam; be-

* *Monthly Notices R. Astr. Soc.* XXV, 237.

coming spotted over with dark points before they finally disappear.

We have thus arrived at the present condition of our knowledge regarding the structure of the incandescent outer surface of the sun, a matter of the greatest moment for the formation of any trustworthy opinions regarding the real nature of the spots or faculæ. We must now return to the spots, and consider the knowledge thus far obtained concerning their motions, real or apparent.

The apparent time of the sun's rotation, as indicated by the motion of the spots, was determined with very tolerable accuracy by the early observers, and Scheiner, in 1626, deduced the position of the axis with close approximation to the truth. Were it certain that the spots were fixed immovably upon the sun, the time of their revolution would clearly be the same as that of the sun's rotation; but this assumption, which was never justifiable, is now known to be incorrect. Then, there is another matter to be borne in mind, viz., that the apparent line of rotation is not the real one; for, since the earth is moving round the sun in the same direction in which he is turning on his axis, a longer period than the true time of rotation must elapse before the rotation would appear complete to an observer on the earth. For example, if a point on the sun appeared to rotate in 28 days, or about the thirteenth part of a year, the earth, our own place of observation, would, during that time, have moved through the thirteenth part of her annual orbit, so that these 28 days would exceed the true time by its thirteenth part, and this true time would be only about 26 days. This last source of error is easily allowed for, but in the former case it is not so. For, if the spots are not stationary upon the sun's surface, we have absolutely no visible fixed point of reference, and are left without landmarks. In fact, such is really the case, and our only means of measuring the period of rotation gives, not that of the sun, but that of some spot which is not fixed. Langier discovered,* in 1846, what abundant observation since then has confirmed, that the periods deduced from different spots are not accordant, although the range of their variation is comparatively small. The most natural course, under the circumstances, is to deduce the period of rotation from as many spots as possible, and to assume that their average represents that of the sun; yet it might well be that all of them have a motion parallel to the sun's equator, and in the same direction, in which case we should be measuring not the period of rota-

* *Comptes Rendus de l'Acad. des Sciences*, 1842, II, 949.

tion, but that of a rotation increased or diminished by the average motion of the spots meanwhile. This is, however, the best that we can do, and all our results are subject to this criticism. We have reason to believe that there is in fact little, if any error from this source, still the question as to currents at the sun's surface thus acquires a double importance. Carrington, of London, devoted seven and a half years, from 1853 to 1861, to daily observation of the position of solar spots. He thus collected 5290 distinct observations, from which it became clearly manifest that the time of rotation of any spot depends upon its latitude upon the sun.* He deduced a formula to express the relation, and this, after correction by Faye, proves to be a very simple one.† It represents the various observations within the limits of their probable errors, and, taken in connection with the small motion of the spots in latitude, discloses the additional fact that any solar currents which exist must be far from powerful; at the same time it raises new and interesting questions as to the agencies which can result in so singular a law. The resultant time for the true rotation is 25·19 days for a point at the sun's equator, but 27·25 days for a spot at 40° of latitude.

This interesting discovery reconciles the perplexing and apparently conflicting observations of various astronomers, by which the same spot, when visible through several successive rotations, has appeared to indicate a different period at each rotation; for it is thus manifest how the phenomenon can result from a slight increase of distance from the sun's equator, such as would be produced by the moderate currents which probably set toward the poles at a rate not exceeding twenty-five miles an hour. These currents cannot be uniform, or very regular; indeed, they may to some extent be produced by means of the spots themselves, and our knowledge regarding them is very limited. It has ever been maintained‡ that their general tendency is toward and not from the equator, a view to which observation seems to lend but little support, ‖ but the possibility of which illustrates the comparatively small amount of motion which really exists, as well as the indefiniteness of our knowledge. A tendency in neighboring spots to approach each other, as bubbles do upon a liquid surface, has sometimes been observed, but more frequently a mutual repulsion; as also a repulsive action of a spot while in the act of breaking out, and the motions thus arising interfere, of course, with our measures of the velocity of rotation.

(To be continued.)

* *Observations of Solar Spots*, &c., p. 224.

† *Comptes Rendus*, LIX, 481; LX, 142; LXVIII, 197.

‡ *Proc. Amer. Assoc. Adv. Science*, 1855, p. 88.

‖ *Carrington, Observations, etc.*, pp 220, 222.

EVOLUTION, AS AFFECTING THE EARTH'S CRUST.

[A Lecture delivered at the Franklin Institute, December 8th, 1870.]

By Prof. Leeds.

(Concluded from page 133.)

At last that great day came when the particles of oxygen and hydrogen had so far decreased in temperature, that is to say, commenced to move in such restricted spheres, that it was possible for them to link their divided existences into one. With that act of union, water—water, the physical life-blood of the world, came into being. Water is to our earth what blood is to the life of man, what sap is to the life of plants. Indeed, water is blood and sap, for they both consist almost entirely of water, to which are added those distinctive elements that give to blood and sap their distinctive character. It has been said, and with truth, that a man is composed of a handful of dust, spread through six pailsful of water. All vegetables and animals are composed of water, together with some charcoal and nitrogen. A great number of the eight hundred species of minerals now known to exist are *hydrates*, that is, consist of from one to forty parts water, along with other ingredients. The tiny particles of water, like fairy ships, more precious to the well being of mankind than Spanish galleons heaped with gold, are freighted with the heat poured down upon the burning sands of the Niger and Amazon, and carry it to the shores of Greenland and the polar seas. Ever at work in our atmosphere, these particles of water are taking heat from this point, where it might harm or kill, and bearing it yonder to nourish and to bless. Water is the great mediator. It is the medium by which animals and plants discharge their functions; by which all parts of our earth, however distant, act and react one upon the other, and by which the physical life of the globe, considered as an organic whole, goes on.

As it is now, so was it in those pre-historic times, before the present geologic day had yet dawned. Heretofore we have been regarding the earth only as a scene of action of those demoniac powers of fire and flame such as the poets fabled Pluto to have reigned over in the abyss of Hades. Hence termed Plutonic forces. But now this blessed mediator makes his appearance, and the life of the world forever emerges from the dreary realms of Night and Chaos, and dwells under the cheerful eye of Heaven. Then, for ages so numerous that our arithmetic fails to count them and our minds to apprehend, a fierce conflict went on between the fiery or Plutonic

and the aqueous or Neptunic agencies. At first did water fare badly in the conflict. In vain did the aqueous particles, at first diffused throughout the atmosphere in the form of vapor, marshal themselves into orderly array, and rain down upon the enemy. Met by the molten surface of the earth, they were repulsed a myriad of times and driven back in rout and confusion. But their fiery enemy was ever growing weaker, until at last he was no longer able to withstand their repeated onslaughts, and the water settled down upon the cooled and hardened crust of the earth, forming an envelope of nearly uniform depth about it.

But, as yet, the shell or pellicle (at first no thicker in proportion to the bulk of the earth than its filmy envelope to the soap bubble) was plastic and yielding in a very high degree. It obeyed the same laws which affected the water above it and the fluid rock beneath. It rose and fell as every onward revolution of the earth brought successive portions beneath the moon. It felt the drawing of the Sun, and Jupiter, and other planets, and was thrown, as the sea is thrown, into conflicting perturbations by their varying influences. It rose and fell upon the tide like some mass of tangled sea-weed upon the face of ocean. And if anywhere it hardened beyond the possibility of yielding, it either cracked, and the basalt flowed from beneath to repair the breach thus made, or it stood firm until some tide higher than all preceding raised the crust into a fold or mountain range.

There were two distinct classes of phenomena which attended the cooling of the globe. In the first place, a cooling of the entire mass, which would diminish the earth's diameter, causing it to shrink away from the hardened crust and leave an open space between core and shell. Secondly, a contraction of the crust itself, which would cause it to break into pieces and fall down into the molten mass below, floating there like so many islands in the sea. If these two contractions went on at the same rate, the surface of the globe would have assumed the form impressed upon it by the balance of its gravitating and centrifugal forces; it would have become a regular ellipsoid, its crust shrinking regularly down with its fluid centre, like a distended India rubber balloon upon a contracting ball within. But nature presents us with a very different state of affairs. There is one gigantic series of mountains upon the earth's surface, and we put them altogether under one name, and call them dry land, and an equally great series of valleys, where is ocean. As remains of temples upon the shores of the Mediter-

ranean, now standing high above the blue waters, show by their worm-eaten sides that at one time they were sunk beneath the surface of the sea and afterwards rose to their present position, so great beds of rock now forming our hills and mountains, which are pierced by marine animals and filled with their shells, must once have been below sea-level. It is by such evidence that we are driven to the conclusion that the lands and seas have undergone vicissitudes almost numberless during the lapse of geological history. A large part, if not all the present terra firma has been beneath the sea, and the sea has been dry land. What are now table lands have been meadows, and where are now the highest mountains have once been valleys. These are mighty changes, and we must look to something equally potent and vast if we would arrive at adequate causes.

Such causes I find to lie in the unequal degree of rapidity with which the fluid nucleus and the hardened crust of the earth contracted. Unequal for two reasons: 1st. Because the rate of cooling of the surface, separated from the intensely cold abysses of space only by a canopy of convecting gases and vapors, was very rapid—much more rapid than the nucleus with its envelope of badly conducting rock. 2d. Because the rate of shrinkage attending the cooling of a rock in the solid, as compared with the liquid condition, is much slower. You all are aware that we employ some liquid, such as alcohol, water or mercury, and not a solid metal, in the construction of thermometers, for the reason that, although the latter would contract on cooling and expand on heating, yet not sufficiently so to indicate slight changes of temperature. Let me recapitulate. In virtue of the more rapid radiation from the surface, the crust would crowd down upon and squeeze the molten mass within. In virtue of the more rapid decrease of volume in a liquid, as compared with the same body in a solid condition, the nucleus would contract away, and leave the crust standing in an arch above it. This arch, unable to bear its own weight, would fold in upon the retreating centre, and thus the surface of the earth would be puckered up into mountain chains and valleys. If, in the process of folding, the surface cracked, its fissures were filled by trap and syenite, basalt, serpentine and granite, which served like mortar to bind the foundation stones of the preadamic world together. If, on the contrary, the crust cooled more rapidly than the nucleus, and pinched the lavas within, it caused them to be projected through the rents with volcanic force.

It is worse than useless to attempt to arrive at valuable conclusions concerning this matter by a simple process of reasoning. Either of the operations alluded to is competent to produce all earth's mountain chains and dykes. The facts necessary to settle the question are within the reach of experiment. After an accurate experimental determination of the amount of contraction of the igneous rocks when in a solid and a fluid condition, it would be possible, by a laborious, though not particularly difficult calculation, to decide the question with mathematical certainty.

Having watched the various stages through which the earth's surface passed, until we have arrived at a time when its continents were raised from the deep and diversified with valleys and hills, let us now turn our attention once more to its atmosphere, and consider the alterations which it underwent during the same interval. We have already, as I pointed out in an earlier portion of the lecture, arrived at a period when the earth had lowered in temperature to such a point that the water forming the ocean and seas could rest upon it. As the process of cooling went on, the vapors were precipitated. The air became clearer, and the fiercely rolling masses of cloud became less vast and dense. Still, no light shone upon the earth as yet, except what came from some yawning crack or awful gulf in the thin crust, where torrents of ancient lava came out from below and spread themselves upon the heaving surface. That you may have some idea of the multitude of such eruptions, I would say that the earth is as full of these vent-holes as a sponge is of pores, or a piece of coral of tubes. The lurid flames illuminated the skies, and, reflected from cloud to cloud, from cloud to earth, were carried from the zenith to the pole, and lit up our planet like a flaming star. But as the vapors grew thinner, the rays of the sun penetrated deeper and deeper, and finally shot down upon the surface.

At first, nought but that portion of the solar beam which is invisible—its heating or calorific rays—attained thus far. Then the darker rays of red made their appearance, and the sun looked down with blood-shot eye upon the surface.

It is doubtful whether, up to this time, and indeed until the light-giving and chemical rays of the sun pierced the terrestrial atmosphere, and the solar beam in all its entirety and completeness penetrated to the earth, any animals and plants existed.

We come now to a question of the gravest importance—one, indeed, that outranks almost every other in its magnitude. We

have been studying the development of the earth's surface, and have seen that up to this point in its history, this development has been of the kind termed Evolution, that is to say, it has been a development of a later from an earlier stage, by the action of purely natural and physical laws, without any break or discontinuity, and without involving the necessity of an extraneous force, or the interposition of a higher power. Now, the evolution which our world's history presents us with is from a lower to a higher stage of development—from the simple to the complex—from what is rudimentary to what is perfected. It has been ever onward in its movement and in its tendency upward. I venture to propose for it the term Progressive Evolution.

Now, the fact that all evolution which the world's history exhibits has been progressive in its tendency, has been a serious difficulty to many. Why, they ask, if one state is derived from another by the unassisted action of physical laws, should we not find that the result of development is sometimes to elevate, but as frequently to degrade? As in the history of nations the operations of purely moral causes has sometimes brought with it wealth, power and culture, at other times has caused great monarchies to lapse into barbarism?

I answer that such is the case in nature. That Evolution is presented to us in two phases, or aspects, one of which is progressive and the other is retrogressive. The sun, the earth, and most probably Venus, Mars and Jupiter are in the progressive phase of evolution, while other planets are in the retrogressive. One of them, the Moon, after passing through all stages of progressive and retrogressive evolution, exhibits the dead, inert, exhausted condition to which a planet is reduced at the close of the downward movement. The accessions of force, including under that term heat, light, electricity and magnetism, derived by the earth from the magazine within and from the sun without, are of such an amount at the present time as to bring the earth into a state peculiarly favorable to the creation and maintenance of all the higher forms of animals and plants. At the beginning, during those stages of evolution to which I called your attention in the earlier portions of the lecture, the process of evolution, though progressive, had not yet advanced to the point at which animal and vegetable life, even of the most rudimentary kind, was possible. Then it passed through long centuries of growth, through the lisping speech and the feeble steps of infancy, when all the forms of life were of the kind that naturalists term embryonic, until manhood was attained. And now we are living far along in its prime. But the same stern reasoning, based upon the unalterable operation of the physical forces, teach us the melancholy truth that a time must come when the supply of heat upon the earth's surface will fall below its expenditure. Then it must pass, as the moon has passed, through all stages of retrogressive evolution, down to death and sheer oblivion.

I said above, that the ordinary operation of physical causes is amply sufficient to account for all the changes which took place upon the earth's surface, up to the time of the appearance of the first germ of something organized, of something which could move of itself, and did not derive the ability of motion from some force without. And if the chemist in his laboratory can produce everything which is not made up of organs, and composed of carbon, nitrogen and the elements of water, in other words, all organic bodies, Nature, which is the greatest of all chemists, could have done the same. Whether nature could have produced the material of which animals and plants are composed—that structure which makes up the walls of a cell, which chemists, looking from a chemical point of view, call Protein, and naturalists, regarding it from a histological stand-point, term Protoplasm—I dare not, without more thought and study than I have yet given to the subject, pronounce an opinion.

There is a matter, however, of still greater importance than the preceding. It deserves to be reckoned of infinite and eternal importance. It is the following:—granting that physical forces could have originated cell-structure, could they ever have determined the formation of a cell, or the aggregation of two or more cells so as to form a living organism?

As yet, all the experiments that have been tried, and all the reasoning which has been brought forward, have failed to show that such an effect could have resulted from material forces alone.

LABORATORY APPLIANCES.

By Prof. Leeds.

New Form of Dessicator.—The dessicator in most common use, as is well known, consists of a low broad glass bottle, the outside of which is fitted by a ground glass joint to a glass cover. The inside is partly filled with fused calcic chloride, and the platinum crucible is supported either upon a glass tripod or upon a platinum triangle. It has the objection that the air in the interior expands when the hot crucible is introduced, and lifting the lid makes it escape. On cooling, a partial vacuum is sometimes produced which renders it difficult to remove the lid. To obviate this difficulty a hole is frequently drilled in the cover. But in doing so it makes the ground glass joint of little benefit, and the apparatus thus arranged is little if any better than a bell-jar set upon a ground glass plate.

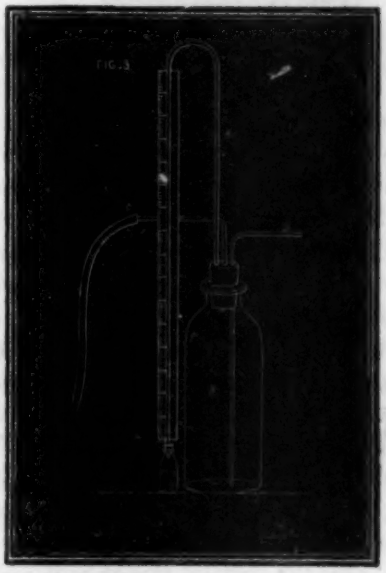
Schrötter's dessicator provides for the free egress of air in contact with the hot crucible. It consists of a bell glass placed upon

a glass plate and containing the crucible. Through a hole in a cork fitted to the tubulure of the bell-jar a fine glass tube is passed to allow an escape of the heated air. This first tube is inclosed in a second tube, somewhat wider, closed at its upper end, and with holes drilled in the lower end, through which the air passes and bubbles up through sulphuric acid contained in the bottom of a third tube that includes the other two. The top of this outer tube terminates in a bulb opening upward, which is filled with calcic chloride. When a partial vacuum is produced in the interior, the air is made to pass through the sulphuric acid before re-entering and thus dried.

A more compact and convenient dessicator is represented in the woodcut. It consists of the base of an alcohol lamp, which is ground into the tubulure of a small bell-jar. The base is partly filled with sulphuric acid, and has a hole drilled in the side near the top to permit the the egress of air. The bottom of the bell-jar is covered with fused calcic chloride and the top by a ground glass plate. One of the two disks which are used to exhibit the cohesion between polished glass surfaces answers nicely. Through the tubulure a funnel with a very large bulb is passed, its end dipping somewhat beneath the surface of sulphuric acid. The platinum crucible is supported in the mouth of the funnel by a triangle. When the air is heated by the introduction of the crucible it bubbles up through the acid and makes its escape by the opening at the side. On cooling, the air forces the acid through the tube and partly fills the funnel, but as soon as the surface of the acid sinks below the end of the tube, air bubbles up through the long column of sulphuric acid until equilibrium is restored. The calcic chloride insures complete drying. It is hardly needful to say that the tube of the funnel is supported in the tubulure by an air-tight joint.

Water Air-Pump.—When the water air-pump is used in connection with a bell-jar and beaker, such as I described in a former

number of this *Journal*, a difficulty is encountered arising from the bursting of air-bubbles contained in the water, so soon as the latter finds itself in a vacuum. In order to obviate this difficulty a number of expedients were resorted to, the one figured in the woodcut proving most satisfactory. To the end of the funnel tube, which is passed through the tubulure of the bell-jar, a very small funnel is connected by a short piece of india-rubber tubing. The ends of the funnel tubes are ground so as to bring them as near as may be in contact. They may be fused, but this not only requires careful workmanship, but was found to be an arrangement very liable to accidents from the rigidity of the parts. The tube of the little funnel is bent in such a way as to bring one of its sides nearly vertical and parallel to the inside of the breaker against which it rests. When now the bubble expands it finds itself hemmed in by the walls of the funnel, and finally breaks quietly and trickles down the vertical side of the funnel until it comes into contact with the beaker.



The exhaust of the water air-pump with which I am working at present is somewhat more than thirty-six feet in length. It is not unusual to have the barometric columns in the gauge rising to the height

of 78 c.m., and to filter under a pressure of 65 c.m. When the vacuum is allowed to stand, the water supply being shut off, the water remaining in the exhaust tube is frequently lifted and runs back. To prevent it from entering the bell-jar the contrivance represented in the above cut was resorted to. The exhaust pipe represented by D enters through the india-rubber cork of a wide-mouthed quart bottle, and passes down almost to its bottom. The tube connecting with the bell-jar to be exhausted C terminates on the inside of the bottle just below the cork, and so likewise does the tube forming the mercury gauge. When the water regurgitates it fills the bottle nearly to the top, but not a drop ever passes over into the bell-jar. On starting a fall of water again through the long exhaust pipe, the water in the bottle is entirely and at once removed by means of the syphon, and the exhaustion of the air follows immediately.

Lecture Experiments.

By Prof. Thomsen, of Copenhagen. Translated by Prof. Leeds from the *Ber. der deutsch. chem. Gesell.* No. 18, Vol. III.

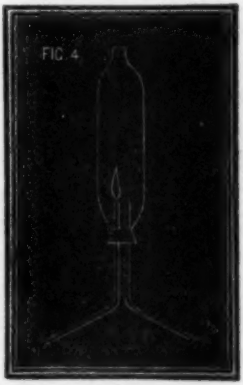
Reciprocal Combustion of the Elements of Water.

This may be demonstrated very instructively in the following manner. A pair of narrow platinum tubes, 1 centimetre long and 1 millimetre diameter are formed up of quite thin platinum foil. These tubuli are melted into a pair of small glass tubes, and are thus made the burners of the two gases, hydrogen and oxygen. The glass tubes are passed through openings about 1 to 1½ centimetres apart in an india-rubber cork. One tube is connected with the oxygen, the other with the hydrogen reservoir. After the cocks of the reservoirs are proportionately opened the hydrogen is ignited. The cork with its two burners is then inserted into a glass tube about 10 to 15 centimetres long with its upper end much narrowed down but still left open. The entire apparatus has then the form shown in the following woodcut.

The hydrogen now burns in oxygen, the fusing together of the orifice of the glass tube being prevented by the end of platinum. If now the cock of the oxygen reservoir be slowly turned off, and the quantity of oxygen so diminished, the point is soon reached at

which the supply becomes insufficient to support the combustion of the hydrogen; the hydrogen flame expands, then disappears for some moments, the flame appears at the oxygen burner, and now without any interruption the oxygen burns in hydrogen. If the oxygen cock be gently opened, the flame withdraws itself to the hydrogen burner, and again hydrogen burns in oxygen. The phenomenon can be repeated as often as desired without extinguishing the flame, provided that the increase or diminution of the stream of oxygen is not made too suddenly.

The experiment is highly captivating, and it is quite impossible for the observer who has not carefully watched it from the beginning to decide which of the two gases indeed is the combustible one. It shows the reciprocity of the combustion in the clearest manner. It is evident that while the oxygen is burning an excess of hydrogen issues from the orifice of the large tube and can be ignited there, so that the combustion of hydrogen in the air, and that of oxygen in the hydrogen, can be shown at the same time.



Combustion of Oxygen with a Sooty Flame.—Heavy hydrocarbons, like benzol and oil of turpentine, burn with a very sooty flame; with a very similar flame oxygen also burns in the vapors of these bodies. The experiment is made in the following manner. Some benzol is warmed to the boiling point in a long necked flask; the flask is closed by a cork with two holes through one of which a glass tube of about 1 centimetre bore is passed and through the other a tube somewhat narrower and bent to one side. When the vapor arrives at the orifice of the wider tube it is lighted, and then a tube through which a slow stream of oxygen is flowing is passed down into the flask through the flame. The oxygen tube is bent above, and its mouth is provided with a platinum tube fused into it. A cork upon the oxygen tube closes the wider tube of the flask. The benzol flame is extinguished and the vapor issues through the side tube, while the oxygen burns in the benzol vapor with a very sooty flame.

Easy demonstration of Oxydation and Reduction and their accompanying change of Weight.—Oxide of copper is rubbed together

with some gum water to a stiff paste, and made into a cylinder of about 1 cent. diameter and 3 cent. length. It is then dried, ignited and reduced by hydrogen at a low temperature. The reduced copper has the form of a cylinder, is very porous, but at the same time, is tenacious enough not to fall into a powder. It is surrounded with some platinum foil, the end of which is fused into a glass tube. Two tubulated bell-glasses, connected by tubes with gas-holders, are now filled, the one with hydrogen the other with oxygen. The mouth of the hydrogen bell opens below, that of the oxygen above. The gases are now allowed to stream through the bells, the copper cylinder is made somewhat warm without allowing it to attain the point of ignition and introduced into the oxygen bell. It forthwith ignites and continues to glow until its oxydation is complete. Then it cools off and the light dies away. When taken out of the oxygen and put in the hydrogen bell it begins to glow fiercely again, much water condenses upon the sides of the bell, while the cylinder is reduced to metallic copper. We have here the highly interesting phenomenon of a body, which burns twice in succession, first in oxygen and then in hydrogen, and both times with the same intense light and heat. After the second burning it is the same body as in the beginning. Since the change of weight in such a cylinder amounts to a gramme, the addition and subtraction can very easily be verified by a common balance.

A LARGE INDUCTION COIL.

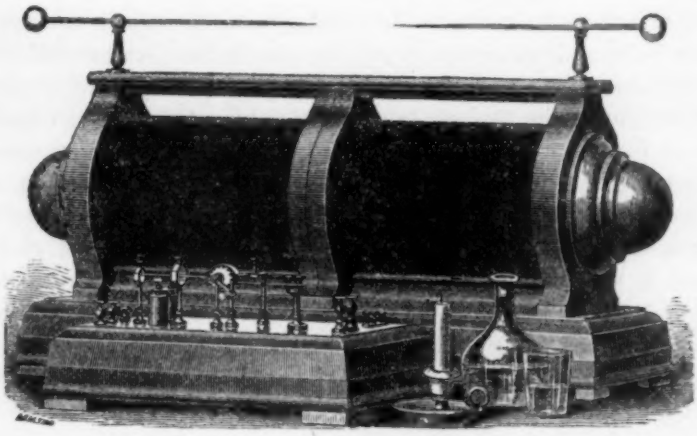
By Wm. H. Wahl, Ph.D.

An induction coil, which we believe to be the most powerful now existing, has been lately constructed by Mr. E. S. Ritchie, of Boston, for Prof. Henry Morton, President of the Stevens Institute of Technology.

Mr. Ritchie, as is well known, was the first, by several fundamental improvements, to make the induction coil an efficient and reliable source of electricity, and it would seem that by constant attention to the subject, and numerous judicious experiments, he has still kept in advance of all other constructors of these instruments, for though Mr. Ritchie's improvements were freely published and at once adopted, in some cases with anything but an ho-

norable acknowledgement, he still seems to surpass all others in the effectiveness and durability of his instruments. Thus, quite lately, a mammoth coil was built for Prof. Pepper, by Mr. App, of London, which was some nine feet in length, contained 150 miles of wire, and weighed nearly a ton. With a battery of some sixty elements, this coil yielded for a while sparks 29 inches in length, but soon failed, and is now, we understand, taken to pieces. The coil, however, now described, containing but 44⅓ miles of wire, 40 inches in length, and weighing about 250 pounds, gives, with but three cells of battery, sparks 21 inches in length, and after several months of constant use and severe tests, is in perfect condition.

The accompanying wood cut, which is a faithful copy from a photograph of the coil, with some familiar objects as standards of



comparison, will give a general idea of its structure and arrangement.

It is made in three parts, one consisting of the condenser, enclosed in a mahogany case, as shown in the foreground, carrying on its upper surface the automatic and hand break piece, commutator, &c., and two others, forming the coil itself. These last are so arranged that they may be separated from each other, and used either apart or united for quantity. The pole cups, by which the halves of the coil and condenser are united, have been omitted by the engraver on account of their confusing effect, as they were superposed by the perspective of the picture.

The particulars of construction are briefly as follows: The

iron core consists of iron wires, about $\frac{1}{16}$th inch thick, and weighs 14 pounds. The thickness of the wires is immaterial except as it affects their annealing. These wires are not insulated from each other, and are simply bound together with a covering of oil silk and cloth, for strength.

The primary wire is 200 feet in length and 0·1655 of an inch, or about $\frac{1}{6}$th of an inch in diameter, and weighs 17 pounds. The secondary wire is 234,100 feet, or about 44⅓ miles, and ·007 of an inch in diameter, and weighs 44½ pounds. It was made of Lake Superior copper, of the best electrical conductivity, and is covered with white silk. It is wound according to the plan devised by Mr. Ritchie, in a series of spirals representing the thickness of the wire and its insulation, and has additional insulation of paraffine paper interposed at regular intervals.

The insulation between the primary and secondary consists of glass bells and vulcanite spools, so proportioned as to offer the greatest resistance at points of highest tension, and proved by actual experiment to be 50 per cent. greater than a spark of 21 inches would penetrate, under the existing conditions. The condenser contains 325 square feet of tin foil insulated with oil silk, 100 square feet being in permanent connection with the primary circuit, and three buttons throwing on 100, 75 and 50 feet respectively, at will.

The break piece is of the combined automatic and hand movement, attached by Mr. Ritchie to all his larger instruments, the automatic break being operated by a single-cell battery, connected or thrown out at pleasure, by a button on the surface of the condenser-case.

The total height to upper surface of horizontal strip is 18½ inches; total length of base, from end to end of round caps over primary, 40 inches; height of base, 5 inches; width of base, 13 inches; length of each section of secondary bobbin, 13 inches; external diameter of secondary bobbins, 9 inches.

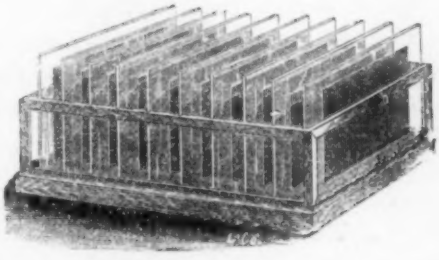
For convenience of transportation and handling, the entire coil, base and all, is divided at the centre, where a vertical crack appears in the drawing, and each half is packed in a separate box. The condenser occupies a third box, and the entire weight, when packed, amounts to 355 pounds.

The battery for exciting this coil was made according to Prof. Morton's direction, by Messrs. Chester Brothers, of New York, and

consists of three glass jars, 10 inches in diameter and 12 inches high, into which are lowered, by means of a windlass, plates of carbon and zinc, 8 × 10 inches, five of each occupying each jar. The liquid employed is the mixture of potassium, bichromate water and sulphuric acid, now used in several forms of battery. When the solution is fresh, an immersion of three inches developes the full power of the coil.

The convenience of this battery for use, Prof. Morton tells us, both at his own laboratory and when lately delivering courses of lecture in Baltimore and Washington, is beyond praise. Sparks of twenty-one inches are developed by this coil with such freedom that there would be no doubt that many inches more might be reached; but, until some important lectures during the present winter are over, he is unwilling to risk the puncture of the insulating bell jars, which would throw the instrument out of use at a critical time; although it has been constructed with a special view to the repair of such a damage, should it occur. At 21 inches Mr. Ritchie warrants the coil as absolutely safe, and constant use during several months has shown, practically, that it is so.

In connection with a leyden jar of $1\frac{1}{3}$ square feet surface, it produces sparks of $2\frac{3}{4}$ inches in length, and with one of Prof. Morton's secondary condensers (see this *Journal*, Vol. LIII, p. 256), shown in the accompanying cut, and containing 20 coated panes, it gives sparks 14 inches in length, and of the intense whiteness and loud report of the Leyden jar discharge.



Blocks of glass three inches thick are penetrated, and seem to represent pretty accurately the same resistance as the 21 inches of air, for when the points are separated 21 inches, and other wires connected with the columns for piercing the glass, several sparks will pass in air before one with a red flash goes through the glass, then several sparks in air will occur before another spark will traverse the glass block again.

Curiously enough, the spark in glass, as in air, seems to render its path a worse conductor than before, for it rarely happens that two sparks in a thick block go, even partially, by the same route,